NASA

ADVANCED ROTORCRAFT TECHNOLOGY AND TILT ROTOR WORKSHOPS

HAA

DECEMBER 2-5, 1980
PALO ALTO, CALIFORNIA

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VOLUME I
Executive Summary

PREFACE

This volume contains an Executive Summary of the Final Report of the Tilt Rotor and Advanced Rotorcraft Technology Workshops held in Palo Alto, CA, on December 2-5, 1980, under the joint auspices of the National Aeronautics and Space Administration and the Helicopter Association of America (subsequently renamed the Helicopter Association International).

June 1981

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INTRODUCTION

On December 3-5, 1980, an Advanced Rotorcraft Technology Workshop was held in Palo Alto, CA, under the joint auspices of the Helicopter Association of America (HAA) and the National Aeronautics and Space Administration (NASA). (Note: In early 1981 the name of the Helicopter Association of America was changed to the Helicopter Association International.)

This workshop was immediately preceded on December 2 by a Tilt Rotor Workshop which was organized on a back-to-back basis by NASA with the support of and in cooperation with the HAA.

In announcing the HAA/NASA Advanced Rotorcraft Technology Workshop, HAA Consultant and Workshop General Chairman, Glen A. Gilbert, said:

> "This Workshop is the continuation of efforts begun in 1978 when the FAA, in cooperation with HAA, developed a five-year Helicopter Operations Development Plan (FAA RD 78-101). In 1979 the FAA and HAA sponsored a workshop to update and recast the plan, with emphasis on industry needs. NASA helicopter experts contributed greatly to the success of that program, and plans were finalized to hold this Workshop to allow NASA a similar industry perspective for its 10-year Advanced Rotorcraft Technology Program.
>
> "Now, then, we are charged with carrying forward this important work. During the Workshop we shall be able to make very effective contributions to the future of the helicopter industry, as well as to our nation's air transportation system in general.
>
> "On behalf of the HAA and NASA, please accept this invitation to participate. I particularly encourage the input of helicopter operators in this Workshop. The end-product will be to the operators' benefit and your guidance is vital. Involvement from manufacturers, of course, also is urged."

With respect to the Tilt Rotor Workshop, General Chairman John Magee of NASA's Ames Research Center, said:

> "Tilt Rotor Workshop '80 is being jointly sponsored by NASA and the HAA because it is believed that the results of the initial tilt rotor flight test program indicate both technological readiness and the potential for significant enhancement of current rotorcraft V/STOL capabilities. The tilt rotor is viewed as a serious contender for the next generation of V/STOL aircraft. The objectives of this Workshop are to:
>
> - Provide the aircraft and rotorcraft communities with an update of the developments and accomplishments in NASA's Tilt Rotor Research Aircraft Program; and

- Provide a forum for industry to guide the planning of the government flight test program to demonstrate and assess the merit of the tilt rotor aircraft for civilian applications."

ORGANIZATION OF WORKSHOPS

The Workshops were organized as follows:

Advanced Rotorcraft Technology Workshop

General Chairman

Glen A. Gilbert
President
Glen A. Gilbert & Associates, Inc.
Washington, D.C. 20037
(Consultant, Helicopter Association of America)

Associate General Chairman

Jay Christensen
Chief, Helicopter Systems Office
NASA Ames Research Center
Moffett Field, CA 94035

NASA Headquarters Liaison

John Ward
Chief, Low-Speed Aircraft Branch
NASA
Washington, D.C. 20545

FAA Liaison

James "Mike" Nelson
Chief, Helicopter Systems Branch
Federal Aviation Administration
Washington, D.C. 20591

DOD Liaison

Col. John Zugschwert
OSD, Department of the Army
Washington, D.C. 20310

Aerodynamics & Structures Session

David Jenney, Chairman
Chief of Technical Engineering
Sikorsky Aircraft
Stratford, CT 06602

Robert J. Huston, Technical Secretary
Chief, Graphite Fibers Risk Analysis
NASA Langley Research Center
Hampton, VA 23665

Flight Control, Avionics Systems & Human Factors Session

Kenneth Jones, Chairman
President, Offshore Logistics, Inc.
Lafayette, LA 70505

C. Thomas Snyder, Technical Secretary
Director of Aeronautics & Flight Systems
NASA Ames Research Center
Moffett Field, CA 94035

Propulsion Session

Charles Kuintzle, Chairman
Assistant General Manager
Avco Lycoming
Stratford, CT 06497

Warner Stewart, Technical Secretary
Director of Aeronautics
NASA Lewis Research Center
Cleveland, OH 44135

Vehicle Configuration Session

Stanley Martin, Jr., Chairman
Director, Advanced Product Design
Bell Helicopter Textron
Ft. Worth, TX 76101

Wally Deckert, Technical Secretary
Chief, V/STOL Aircraft Technology
NASA Ames Research Center
Moffett Field, CA 94035

Tilt Rotor Workshop

John Magee, General Chairman

Jim Lane

Demo Guilianetti

Tilt Rotor Aircraft Office
NASA Ames Research Center
Moffett Field, CA 94035

Glen A. Gilbert
HAA Liaison

ADVISORS

To serve as advisors in preparing for and conducting the workshops, the following individuals were named by the General Chairman:

Vincent Colicci
President
Helicopter Services, Inc.
(Chairman, Board of Directors,
Helicopter Association of America)

Dr. Leonard Roberts
Director, Aeronautics and Flight Systems
NASA-Ames Research Center

William Snyder
Head, Aeromechanics Technology
NASA-Ames Research Center

Delford Smith
president
Evergreen Helicopters, Inc.
(President, Helicopter Association
of America)

Robert A. Richardson
Executive Director
Helicopter Association of America

Robert Suggs
President
Petroleum Helicopters, Inc.
(Past President, Helicopter
Association of America)

John Kerr
Vice President-Engineering
and Development
Hughes Helicopters
(President, American Helicopter Society)

Lynn Keston
Executive Director
American Helicopter Society

Joseph Mashman
Vice President-Special Projects
Bell Helicopter Textron

K.I. Grina
Vice President-Engineering
Boeing Vertol Co.

C.J. Benner
President
Aerospatiale Helicopter Corp.

Carl Perry
Executive Vice President
Hughes Helicopters

Robert Daniell
Executive Vice President-
Engineering & Programs
Sikorsky Aircraft

PROGRAM PLAN

The basic program plan of the two workshops was as follows:

December 2 - Tilt Rotor

AM - XV-15 (Tilt Rotor) Flight at Ames
Tilt Rotor Briefing

PM - Workshop Session
Overview
Concept Evaluation
Panel Discussion

December 3 - Advanced Rotorcraft Technology

AM - Opening Plenary Session
NASA R&D Overview
Operators' Views

PM - Operators' Views (cont'd.)
Workshop Sessions and Subsessions

December 4 - Advanced Rotorcraft Technology

All Day - Workshop Sessions and Subsessions (cont'd.)

December 5 - Advanced Rotorcraft Technology

AM - Closing Plenary Session
Workshop Session Chairmen and Technical Secretaries' Reports
Wrap-up

Noon - Closing Reception and Luncheon
Guest Speaker

ORGANIZATION OF FINAL REPORT

The Final Report of the two workshops is organized into seven volumes as follows:

SPECIAL PAPERS

NASA R&D Overview

An overview of NASA's rotorcraft R&D program, which was given by John Ward at the opening plenary session is reproduced in Appendix A of this volume.

Prinsendam Rescue

Appendix B contains the presentation made by guest speaker Commander Richard Schoel at the closing luncheon.

WORKSHOP REGISTRANTS

Tilt Rotor

Appendix C

Advanced Rotorcraft Technology

Appendix D

EXECUTIVE SUMMARY OF VOLUMES III - VII

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Appendix E

Flight Control, Avionics Systems and Human Factors Session

Appendix F

Propulsion Session

Appendix G

Vehicle Configuration Session

Appendix H

Tilt Rotor Session

Appendix I

KEYNOTE PRESENTATION

by

John F. Ward
Aeronautical Systems Division
National Aeronautics and Space Administration
Washington, D.C.

OVERVIEW-NASA ROTORCRAFT R&D PROGRAM

The purpose of this presentation is to provide an overview of the NASA Rotorcraft Program (Figure 1) as an introduction to the technical sessions of the HAA/NASA Advanced Rotorcraft Technology Workshop. The presentation will deal with the basis for NASA's increasing emphasis on rotorcraft technology, NASA's research capabilities, recent program planning efforts, highlights of its 10-year plan and future directions and opportunities.

Civil Market Growth

The key factors forming the basis for increased emphasis on rotorcraft technology are shown in Figure 2. These include the growing magnitude of the world-wide utilization of helicopters for civil and military missions since the helicopter's introduction in the early 1940's. While military applications have been many and are well established, there is a new, major growth in the world civil helicopter fleet. This world civil market potential has stimulated strong competition between the free world helicopter manufacturers. The United States, Europe and Japan are moving aggressively to supply the world markets. In this competitive situation there is a high payoff in the application of advanced technology. This is especially true in the helicopter industry where it is estimated that the technology is about 50-percent mature. This is contrasted with the fixed wing industry which is estimated to be 90-percent mature. It is this need for increased technical maturity that suggests that NASA is in a position to make some significant contributions. NASA, and the predecessor NACA, have been involved in rotorcraft research since the mid-1930's, utilizing a growing number of unique research facilities and a research staff possessing important expertise.

The international market for civil rotorcraft is growing rapidly and includes a wide variety of applications. Some of these are listed in Figure 3. One of the largest uses is in resource exploration and development with primary use being off-shore oil exploration in the Gulf of Mexico, North Sea, Alaska, and the Atlantic Coast of the United States. The use of helicopters in support of coal mining operations is now well established in Appalachia. Increasing use is being made of the helicopter in forest management and agriculture. The advantage offered in forestry application is the capability of selective harvesting which minimizes the environmental impact. Currently, helicopters represent 10-percent of the agricultural aircraft fleet and these vehicles are doing 20-percent of the spray work. The use of helicopters for special construction has been growing and includes power line construction, pipe line construction, and material transport to remote sites. The public service application for helicopters is just beginning to be generally recognized and accepted by communities. Police, fire, and ambulence services are but a few of the growing applications. NASA sponsored a Public Service Helicopter Users' Workshop last July (1980). (An overview of the workshop results is contained in Volume II.) The use of the helicopter in civil passenger transportation is growing rapidly in the executive transport role. In addition, the scheduled transport of oil-rig crews has evolved into large air transportation systems which may be the forerunner of viable commercial short-haul transportation networks utilizing large transport helicopters.

The growth trends in the helicopter industry are shown in Figure 4, which illustrates the number of aircraft, heliports, and operators over the period from 1970 into the 1990's - a period of increasing actual and anticipated growth. The growth rates have exceeded 10-percent per year and have recently reached 15 to 18-percent in the number of helicopters operating in the United States. Similar trends exist for the balance of the world wide fleet which together with the U.S. civil fleet totals approximately 20,000 aircraft.

While there are strong indications of continued growth in the civil helicopter industry, the rotary wing market still has not reached the point of "takeoff" enjoyed by the fixed wing markets in the 1960's. The relative positions of the fixed wing and rotary wing markets are shown in Figure 5. As indicated, the breakthrough in the fixed wing markets was firmly established when the manufacturers could commit to a new aircraft based on proven design and analytic capability with assurance that the final product could be produced to specifications with low technical risk. We have not reached this level of technical maturity in the rotary wing industry and this element of technical risk may threaten the continued growth of the industry. It is this issue of technical risk reduction that is a key reason NASA has begun to place increased emphasis on rotorcraft technology.

Technology Benefits

The introduction of new technology into new designs has successfully been accomplished in the current civil designs such as the Sikorsky S-76, the Bell 222, and the Aerospatiale Astar. Even greater benefits can be achieved in the future (Figures 6 and 7). In the area of aerodynamics, the application of advance airfoils, blade planform, rotor configurations and active control systems can result in reduced noise and vibration and improved efficiency. Full all-weather operation capability in remote sites and high density terminal areas will result from the introduction of more advanced displays, sensors, fly-by-wire/light, and on-board guidance and navigation, including the utilization of satellite positioning systems. Increased propulsion system reliability will result from the application of advanced materials, designs with fewer parts and automatic diagnostics. In the area of structures and materials more reliable and lighter weight structures will result from a better definition of design loads and operating environment, improved analytical methods, and advanced fabrication techniques.

NASA Capabilities

NASA is in a unique position to assist in the development of advanced rotorcraft technology as a result of special research facilities, expertise and organizational structure as shown in Figure 8. The organization involves four research centers. Ames Research Center, Moffett Field, California, is the lead center with emphasis on aeromechanics, aeroelasticity, flight dynamics and control, flight operations, simulation and human factors. The Langley Research Center, Hampton, Virginia supports rotorcraft structures research which includes materials and structures, aeroelasticity, dynamics, rotor/airframe aerodynamics, acoustic theory and internal noise. The Lewis Research Center, Cleveland, Ohio, conducts propulsion research including rotorcraft transmissions, small engines, and icing research. The fourth center is the Dryden Flight Research Center, Edwards, California where high-risk flight testing and envelope documentation flights of new research aircraft are conducted.

All NASA rotorcraft is carried on with direct participation and close coordination with co-located laboratories of the Army Aviation Research and Devleopment Command (AVRADCOM). In addition to the co-located labs at the Ames, Langley, Lewis and Dryden Centers, NASA works closely with the Army's Applied Technology Laboratory at Ft. Eustis, Virginia. This close working relationship with the Army research team has significant benefits resulting from joint efforts on research of mutual interest.

A broad range of NASA research facilities are available for conducting investigations of benefit to rotorcraft. Some of the ground-based facilities are illustrated in Figure 9. The Ames facilities include the 40- x 80-ft. Wind Tunnel which is now being modified to provide an 80- x 120-ft. test section and increased speed capability in the 40- x 80-ft. test section. The 11- x 11-ft. Transonic Tunnel at Ames is now capable of of rotor blade dynamic stall testing with new oscillating air-foil equipment being installed. The third category at Ames is the extensive ground-based flight simulators including the Flight Simulator for Advanced Aircraft and the newly operational Vertical Motion Simulator. Among the many facilities that can be used for rotorcraft research at the Langley Research Center are the Transonic Dynamics Tunnel (TDT) and the 4- x 7-meter Wind Tunnel. The TDT is unique in that Mach number and Reynold's number scaling can be achieved simultaneously by testing dynamic models in the Freon atmosphere. The Lewis Research Center has a wide array of ground-based test facilities including transmission test facilities, gear test rigs, engine test stands and propulsion system wind tunnel. In addition, a unique 9- x 6-ft. icing wind tunnel facility is available which is now being used for helicopter component icing investigations.

NASA has a number of rotorcraft flight research aircraft. A number of these are shown in Figure 10. All of these aircraft are based at the Ames Research Center. The Rotor Systems - search Aircraft (upper left) is a research aircraft designed, fabricated, and flight qualified under a joint NASA/Army program. The vehicle shown is in the compound helicopter configuration. A second vehicle is also being flight tested in the pure helicopter configuration. These aircraft have special systems and extensive instrumentation for conducting in-flight research on rotor systems. The XV-15 Tilt Rotor Research Aircraft (upper right) is one of two vehicles now on flight status. The design, fabrication, and flight qualification of these aircraft were also carried out as a joint NASA/Army program. In addition, the

Navy has joined the program to obtain tilt rotor data for their V/STOL assessment activities. The XV-15 is currently engaged in a proof-of-concept flight test program.

The CH-53 helicopter (middle row, left) was recently transferred to the FAA, Atlantic City, for their use in helicopter IFR investigations. NASA had used this aircraft for guidance and navigation and ride quality research. The NASA guidance and navigation research will now be carried on with the SH-3 helicopter (middle row, center) which has recently been totally refurbished. The CH-47 helicopter is specially equipped as a variable stability research vehicle and is being modified for on-board generation of display formats in preparation for terminal area automatic landing research. The bottom row of aircraft are the UH-1H helicopter on the left, which is used for flight control and MLS research; and the AH-1G vehicle which is now engaged in flight tests to obtain rotor airloads and noise data which will be used as baseline data for the development and validation of noise prediction methodology.

Program Planning

As indicated in Figure 11, in 1978 the NASA Office of Aeronautics and Space Technology established a special in-house Rotorcraft Task Force to assess the technology needs and develop a long-range research plan. Arrangements were made with the National Research Council to form an ad hoc Committee on Rotorcraft Technology to review and critique the proposed NASA 10-year planning effort. This ad hoc Committee included representatives of the helicopter and engine manufacturers, operators, universities, FAA, Army and Navy. Subsequent reviews of the program plans and progress have been carried out by the NASA Aeronautics Advisory Committee through the ad hoc Subcommittee on Rotorcraft.

The initial step in the Task Force effort was to establish the critical areas requiring attention. These critical needs are shown in Figure 12. These needs have been identified and confirmed in numerous meetings with the civil and military helicopter community and form the basis for the development of the NASA rotorcraft technology plan.

Highlight of Plan

The resulting plan is illustrated in Figure 13, which presents the elements of an augmented program over a ten-year period. The program is presented in the categories of aerodynamics and structures, propulsion, flight control and avionic systems, and vehicle configurations. The ongoing program in rotorcraft technology amounts to approximately $25M per year. It is divided into four categories of research: (1) Research and Technology Base - aerodynamics, aeroelasticity, dynamic stall, flight operations, guidance and navigation; (2) Studies; (3) Systems Technology - operating systems, advanced rotors, and helicopter transmissions; and (4) Experimental Aircraft - Rotor Systems Research Aircraft, and Tilt Rotor Research Aircraft. The 10-year plan builds upon the ongoing effort and has a total funding requirement of approximately $500M over the 10-year period.

The next series of charts depict some of the key elements of the 10-year plan. These will serve as a short summary of the type of program elements that will be discussed in the Workshop technical sessions.

Aerodynamics and Structures - In the area of aero/acoustics (Figure 14) the emphasis is placed on the development and verification of analytical methods for the prediction of rotor/airframe interaction aerodynamics. This involves isolated rotor testing at small-scale and large-scale in addition to rotor/airframe testing in the wind tunnels. Selected flight testing will also be conducted utilizing the Rotor Systems Research Aircraft. New emphasis will also be placed on rotor acoustics (Figure 15) in order to evolve a comprehensive rotor source noise analysis. The critical factor here is the need for accurate, simultaneous rotor airloads data and measured noise data under precisely controlled conditions.

Vibration reduction is addressed by placing early emphasis on an assessment of the adequacy of the state-of-the-art of airframe analytical modeling. This effort, illustrated in Figure 16, already started at the Langley Research Center, involves the review of finite element analytical methods and the analysis of existing airframes using the NASTRAN structural dynamics finite element computer program. This first phase of the effort is underway and features a NASA/Industry Steering Group to assure the wide dissemination of the results throughout the helicopter industry. Later, if necessary, shake tests of the modeled airframe will be conducted to conclusively verify the accuracy of available analytical methods and document any shortcomings needing further attention.

Another element of the program is related to the application of advanced composite materials to the design of helicopter airframes (Figure 17). This research will be focused on the unique requirements for helicopter design such as large cutouts, highly loaded primary structure, thin gauge design techniques, and damage-tolerant designs. This program activity will be coordinated with the Army's Advanced Composite Airframe Program (ACAP) and is aimed at follow-on efforts in advanced composites. As the ACAP program progresses, additional technology needs may be identified and NASA's composite effort will be adjusted as appropriate.

<u>Propulsion</u> - The propulsion program element that evolved from

the planning process starts with emphasis on small engine components and with the goal of providing the technology for the design of reliable turbine engines in the size range of 300 to 500 horsepower. This program would involve research on small components such as compressors, turbines, combustors, fuel control, and diagnostics. The research approach would start with the initial development of advanced analytical methods, proceed to the testing of small components to validate and guide the development of the design tools. Later stages of the program would involve systems tests and experimental demonstration of an advanced small turbine engine.

The propulsion plan also includes continuing research on advanced transmissions (Figure 19). This would be an augmentation of the ongoing effort in power transfer which involves the application of advanced technology in bearings, gears, seals, and lubricants to the improvement of conventional transmissions. This research at Lewis Research Center is now producing significant results. Another activity showing considerable promise is the research underway at Lewis in hybrid transmission technology which combines the advantages of traction drive and advanced gear technology for the unique requirements of helicopter power transfer where very high speed reduction ratios from engine to main rotor are required.

The power transfer and engine technology effort also includes an effort that is just starting on convertible propulsion system technology (Figure 20). In addition to a study effort that will look at the potential of convertible propulsion systems in the 1990's, and the specific research needed to support this technology; a joint NASA/DARPA program has just been initiated to begin experimental investigation of a convertible fan/shaft engine and control system in order to identify and explore critical technology.

Flight Control and Avionic Systems - Early activity in the area of all-weather flight operations deals with remote site guidance and navigation (Figure 21). The emphasis here is on operations over land utilizing passive ground equipment, on-board radar, and advanced displays. This program area also includes work on icing, low airspeed systems and precision low altitude guidance and navigation (e.g. Global Positioning System applications). The remote site research will be followed by augmented efforts in high-density terminal area operations.

Vehicle Configurations - The integration of the advanced rotorcraft technology into new and improved vehicles is a key element of the overall program. Two classes of vehicles are addressed: high speed rotorcraft and large cargo/transport rotorcraft. Each of these categories offer future benefits and opportunities in both civil and military application. In the case of high speed vehicles (Figure 22) there are a number of promising concepts requiring further study. Examples include the X-wing concept, advanced tilt rotor, the Advancing Blade Concept, and a reassessment of the compound helicopter based on advanced rotors and convertible propulsion system technology. NASA's ongoing program provides a foundation for these studies through model tests, simulation, and flight tests of available research vehicles. This work would be significantly augmented in the proposed plans.

In regard to large rotorcraft, the emphasis will include an assessment of the future potential of the various configurations that appear promising for large size vehicles (Figure 23). The objective is to determine the benefits available from applying advanced technology to vehicle concepts including the tilting and non-tilting quad-rotor, warm cycle rotor tip-reaction drive, and shaft driven single and tandem rotor configurations. The purpose of the proposed research is to provide a broad based technology in large rotorcraft concepts and systems to enable potential users and manufacturers to make minimum risk decisions regarding vehicle development options. A target of opportunity that is being explored is the possibility of conducting a joint NASA/Army large rotorcraft flight research program utilizing the assets of the XCH-62A Heavy Lift Helicopter. A related effort is currently underway by NASA using the aft transmission hardware from the XCH-62A (shown in Figure 24) in a program to develop and verify improved finite element analyses for the prediction of large spiral bevel gear loads and stresses.

Summary

The technical approach taken in the Advanced Rotorcraft Technology Program is outlined in Figure 25. The main elements include the development of advanced design methodology, the validation of that methodology, and the exploration of new and improved vehicle configurations incorporating advanced technology. To date, we have initiated the first stages of the overall program (Figure 26) utilizing funding made available by Congress as a special "add-on" to NASA's Fiscal Year 1980 budget and additional funding approved in the Fiscal Year 1981 budget cycle. The history of the NASA Rotorcraft Program funding levels is shown in Figure 27. We have been successful in maintaining a continued growth in our program through 1983. We are currently preparing to begin the planning review and advocacy for 1983 and beyond.

Overall, the future growth of the rotorcraft markets, wide diversity of potential applications, and opportunities for major improvements offered by new technology suggest a number of new opportunities in the 1990's which include the examples given in Figure 28. Quiet, jet-smooth, all-weather rotorcraft can be provided for expanded roles in executive, commercial, utility, and public service operations. In the special purpose and commercial short-haul transport role there are potential opportunities for increasing the capacity of passenger vehicles from the near-term size of 60-passenger up to sizes of 200-passengers where the resulting direct operating costs become competitive with other short-haul aircraft. The associated benefits of relieving hub airport congestion are also desirable. In the cargo role there is a potential for payloads to 75 tons with further capability in hybrid airships (quad-rotor plus bouyant hull) to payloads 150 tons and higher. This heavy-lift potential could have a significant impact on the world industrial siting and distribution systems of the future. While the above opportunities are civil oriented, the potential benefits to future military rotorcraft capabilities are equally important.

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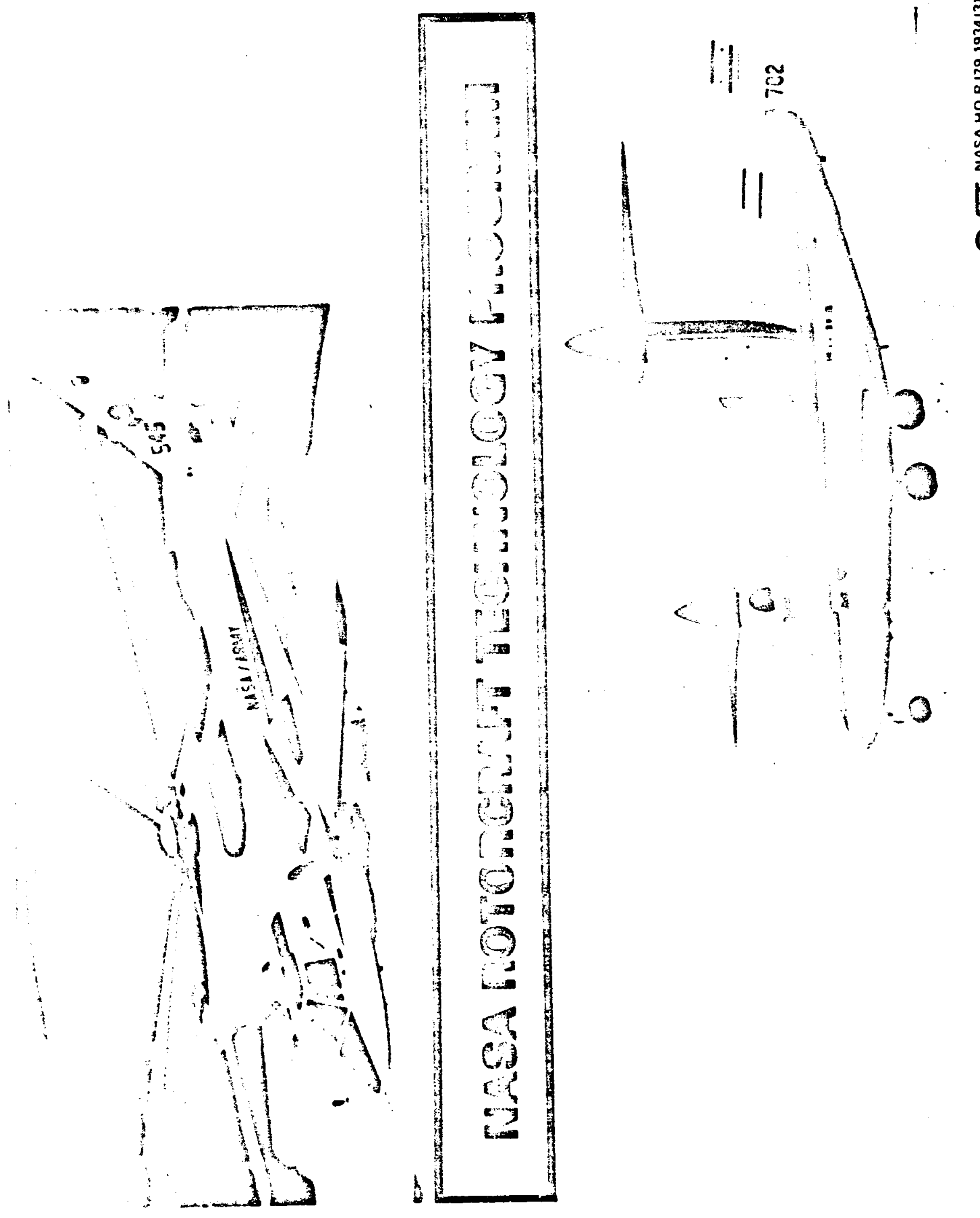

Figure 1.

BASIS FOR ROTORCRAFT EMPHASIS

- MAGNITUDE OF WORLD MARKET
- CIVIL AND MILITARY USE GROWTH
- FOREIGN COMPETITION
- HIGH PAYOFF IN APPLICATIONS OF ADVANCED TECHNOLOGY
- NASA IN POSITION TO MAKE SIGNIFICANT CONTRIBUTIONS

NASA

Figure 2.

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INTERNATIONAL ROTORCRAFT MARKETS

- RESOURCE EXPLORATION
- FOREST MANAGEMENT AND AGRICULTURE
- CONSTRUCTION
- PUBLIC SERVICE
- PASSENGER TRANSPORTATION

NASA

Figure 3.

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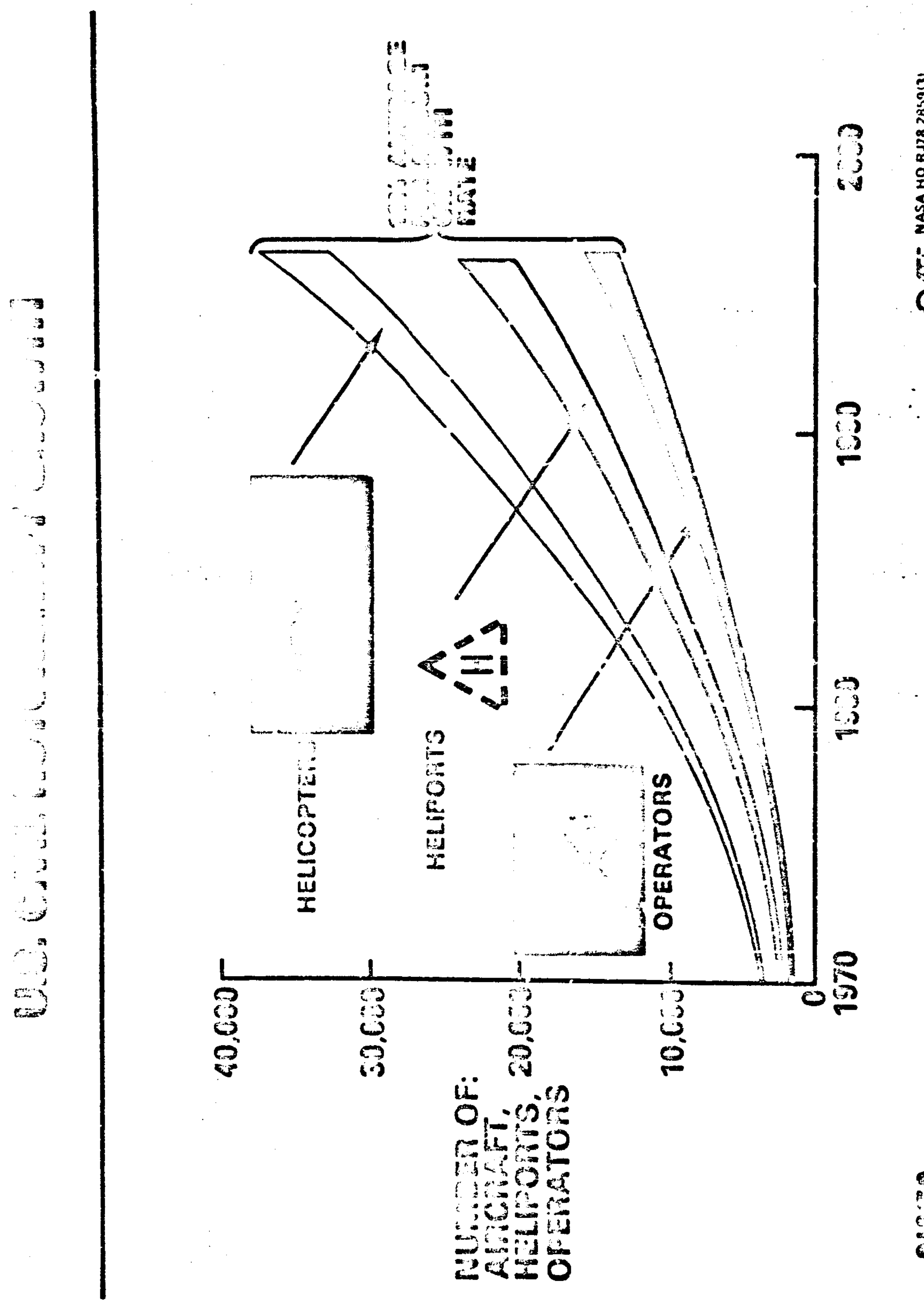

Figure 4.

WHAT ROTARY WING NEEDS TO ACHIEVE INDUSTRY "TAKEOFF"

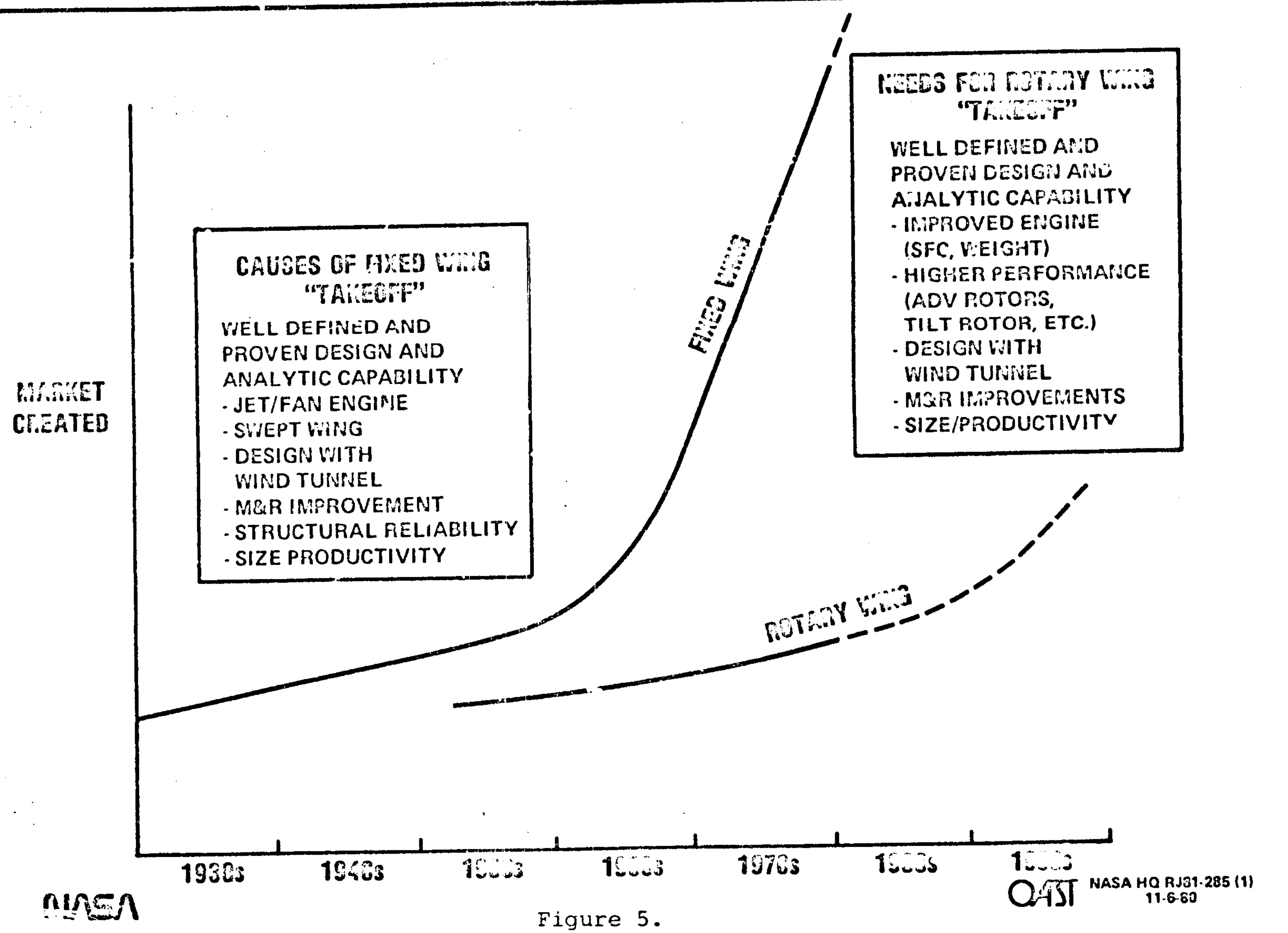

Figure 5.

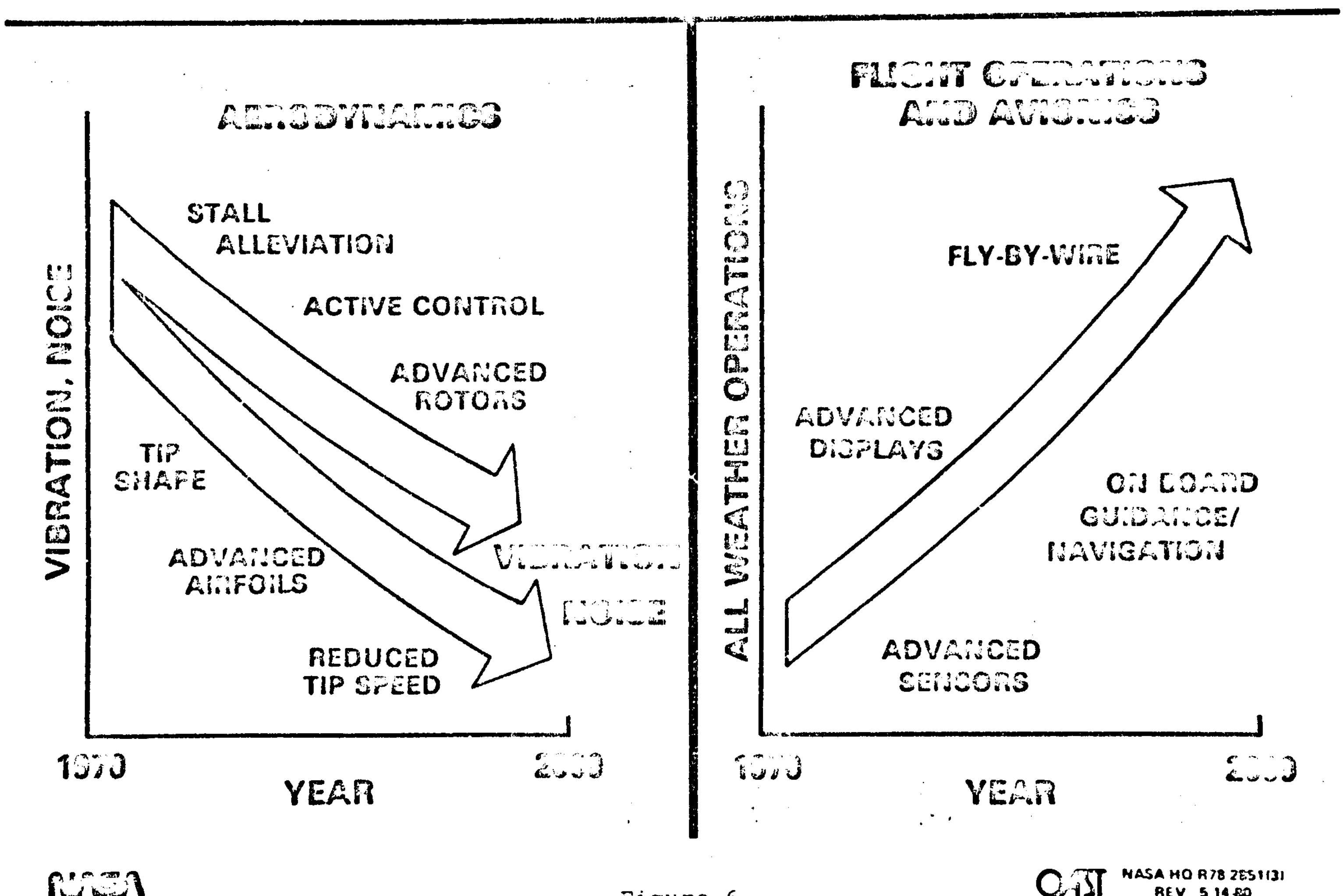
AERODYNAMICS
STALL
ALLEVIATION
ACTIVE CONTROL
ADVANCED
ROTORS
TIP
SHAPE
ADVANCED
AIRFOILS
REDUCED
TIP SPEED
VIBRATION
NOISE
VIBRATION, NOISE
1970
2000
YEAR
FLIGHT OPERATIONS
AND AVIONICS
FLY-BY-WIRE
ADVANCED
DISPLAYS
ON BOARD
GUIDANCE/
NAVIGATION
ADVANCED
SENSORS
ALL WEATHER OPERATIONS
1970
2000
YEAR
NASA
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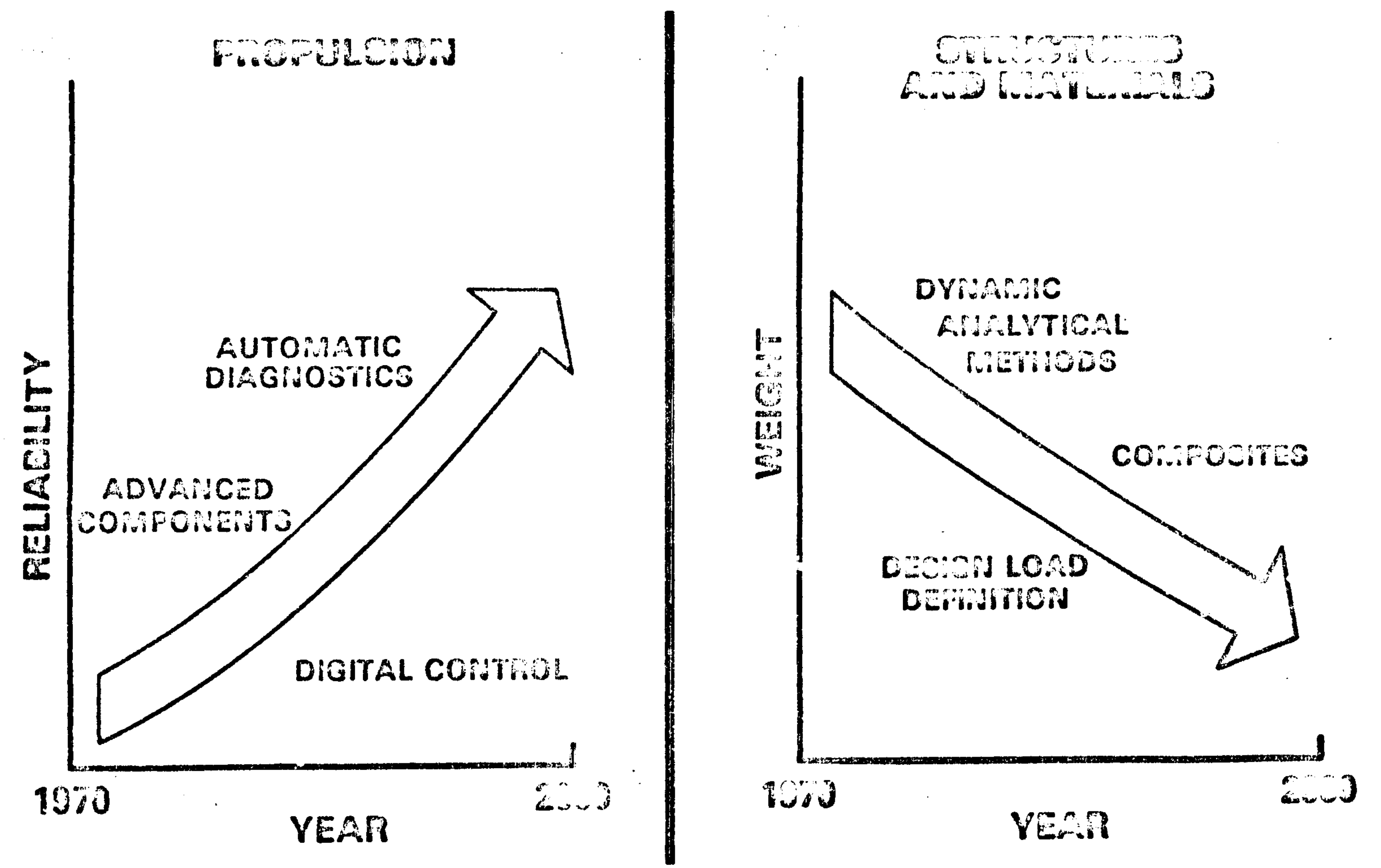
Figure 6.



NASA

Figure 7.

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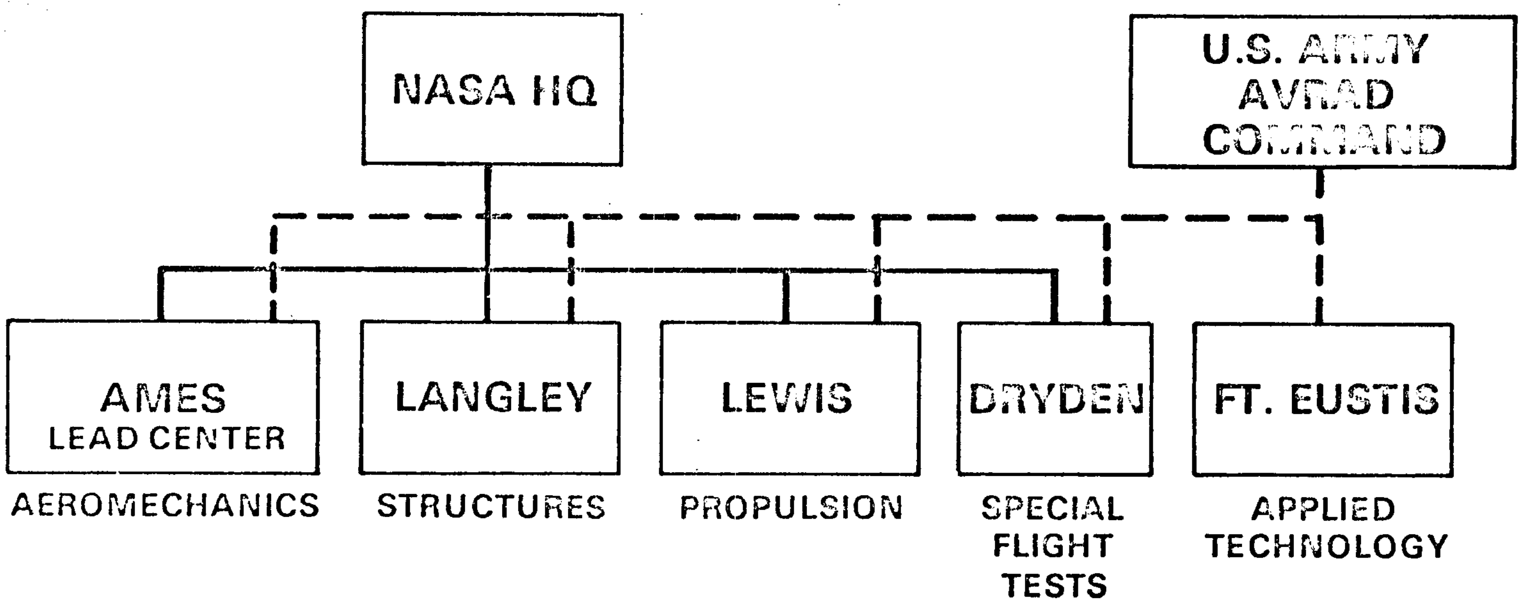
NASA ORGANIZATION OF EFFORT



- CONDUCT RESEARCH AND TECHNOLOGY DEVELOPMENT
- OPERATE UNIQUE FACILITIES

Figure 8.

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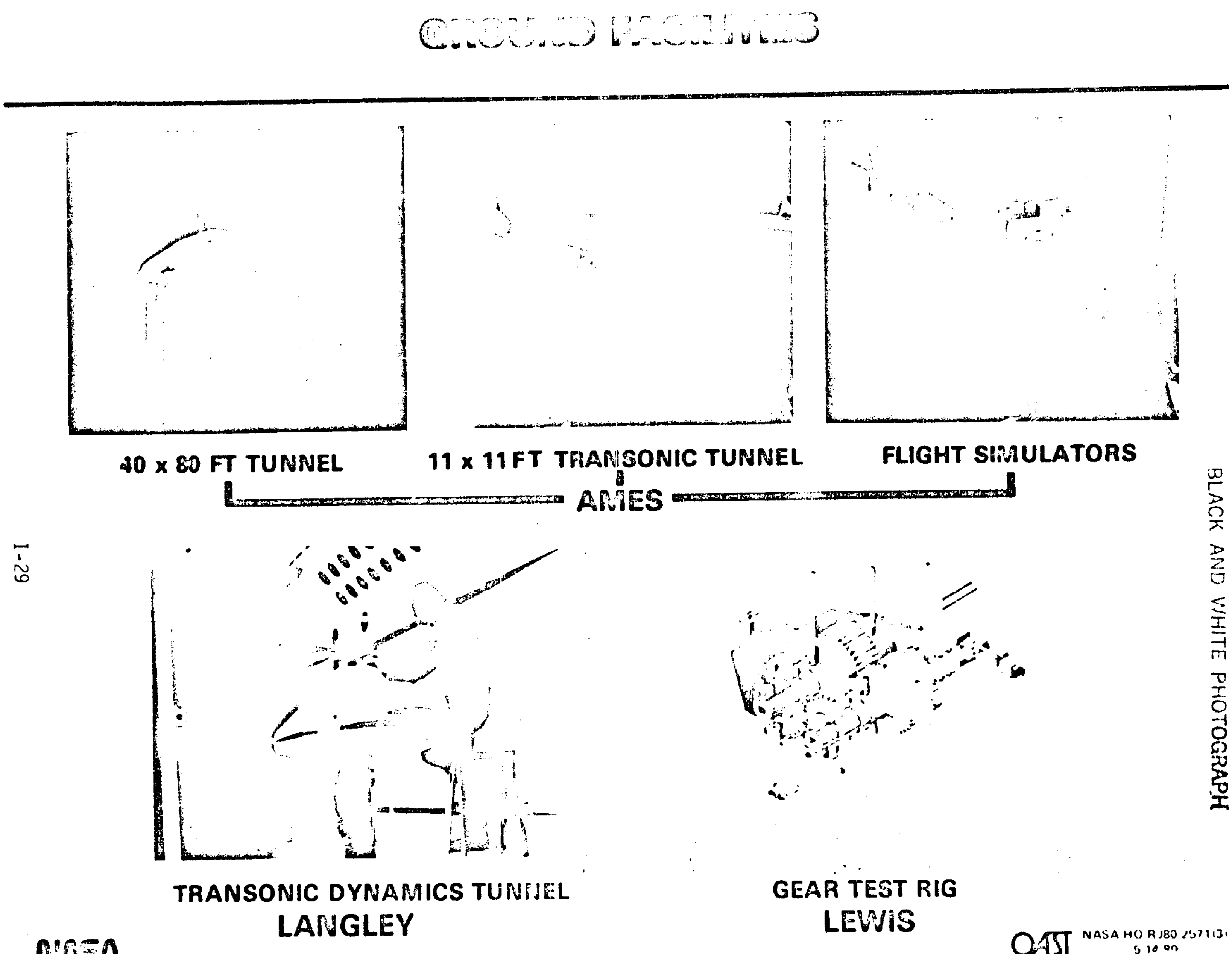

Figure 9.

RESEARCH AIRCRAFT

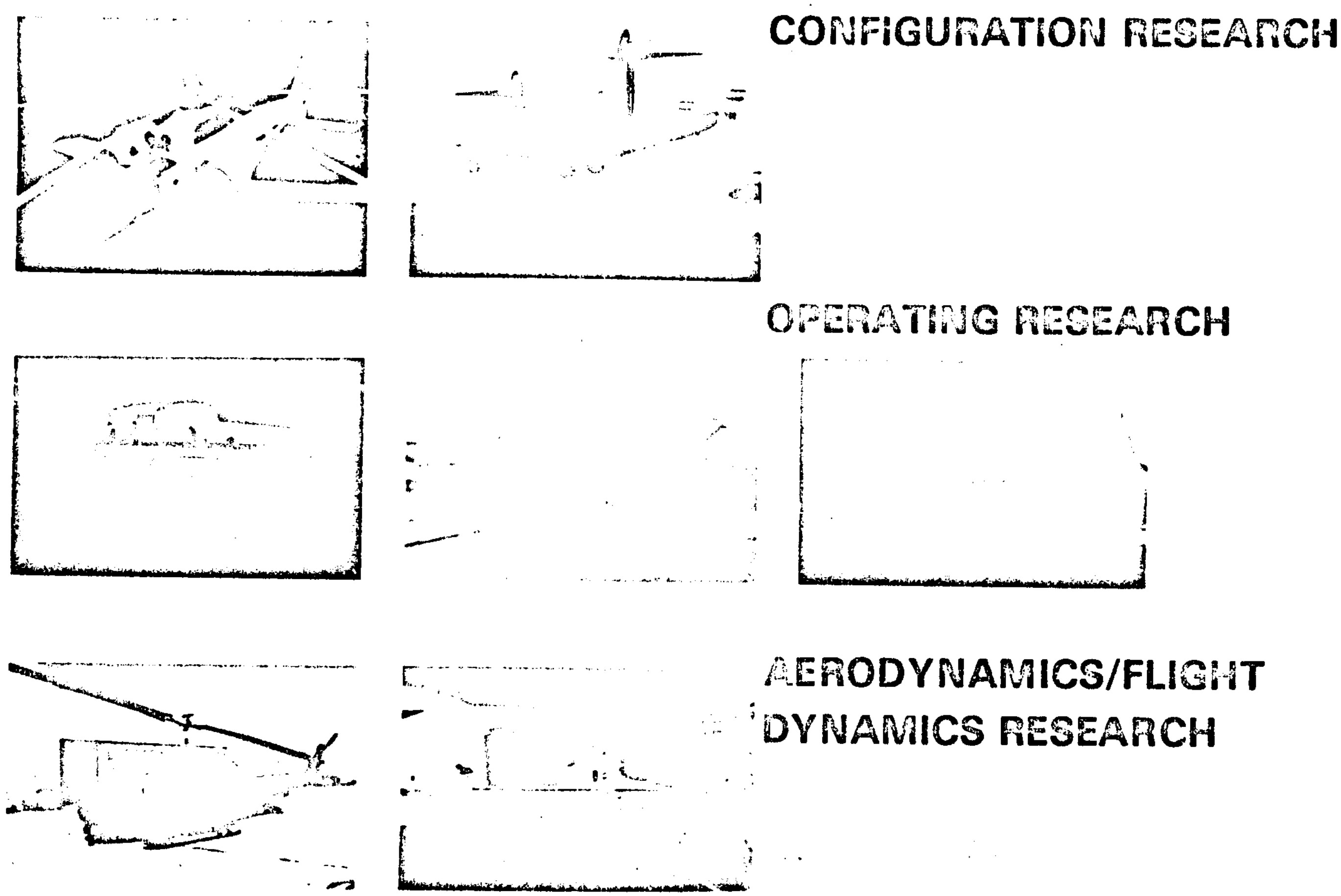

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Figure 10.

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PROGRAM PLANNING

1978

- ROTORCRAFT TASK FORCE
- NATIONAL RESEARCH COUNCIL
  - AERONAUTICS AND SPACE ENGINEERING BOARD
  - AD HOC COMMITTEE ON ROTORCRAFT TECHNOLOGY*

1979/80

- NASA AERONAUTICS ADVISORY COMMITTEE
  - INFORMAL SUBCOMMITTEE ON ROTORCRAFT TECHNOLOGY*

*MEMBERSHIP:	GOVERNMENT AND INDUSTRY
PURPOSE:	ADVISE NASA ON TECHNOLOGY NEEDS AND PRIORITIES
OUTPUT:	RECOMMENDATIONS TO NASA MANAGEMENT

NASA

Figure 11.

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ROTORCRAFT

CRITICAL REQUIREMENTS

• NOISE REDUCTION • VIBRATION REDUCTION • FLYING/RIDE QUALITY IMPROVEMENT • SAFETY IMPROVEMENTS	TO ENHANCE PASSENGER, COMMUNITY, AND PILOT ACCEPTANCE
• RELIABILITY AND MAINTAINABILITY (R&M) IMPROVEMENT • ALL-WEATHER CAPABILITY • PRODUCTIVITY IMPROVEMENT • REDUCED FUEL CONSUMPTION	TO ENHANCE ECONOMIC VIABILITY

FROM: ADVANCED ROTORCRAFT TECHNOLOGY TASK FORCE REPORT, OCT. 15, 1978

NASA

OAST NASA HQ RJ80-2582(1) 5-14-80

Figure 12.

ADVANCED ROTORCRAFT TECHNOLOGY

PROGRAM ELEMENTS

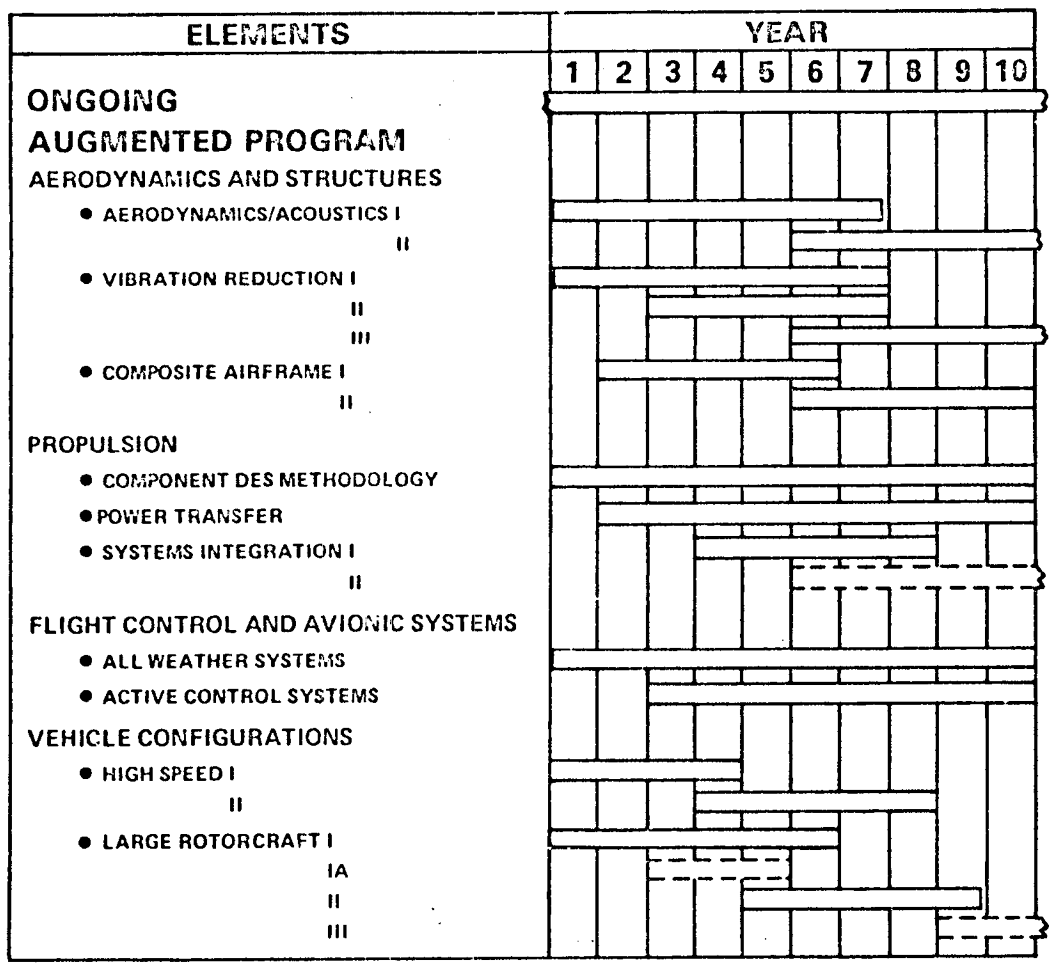

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Figure 13.

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5-14-80

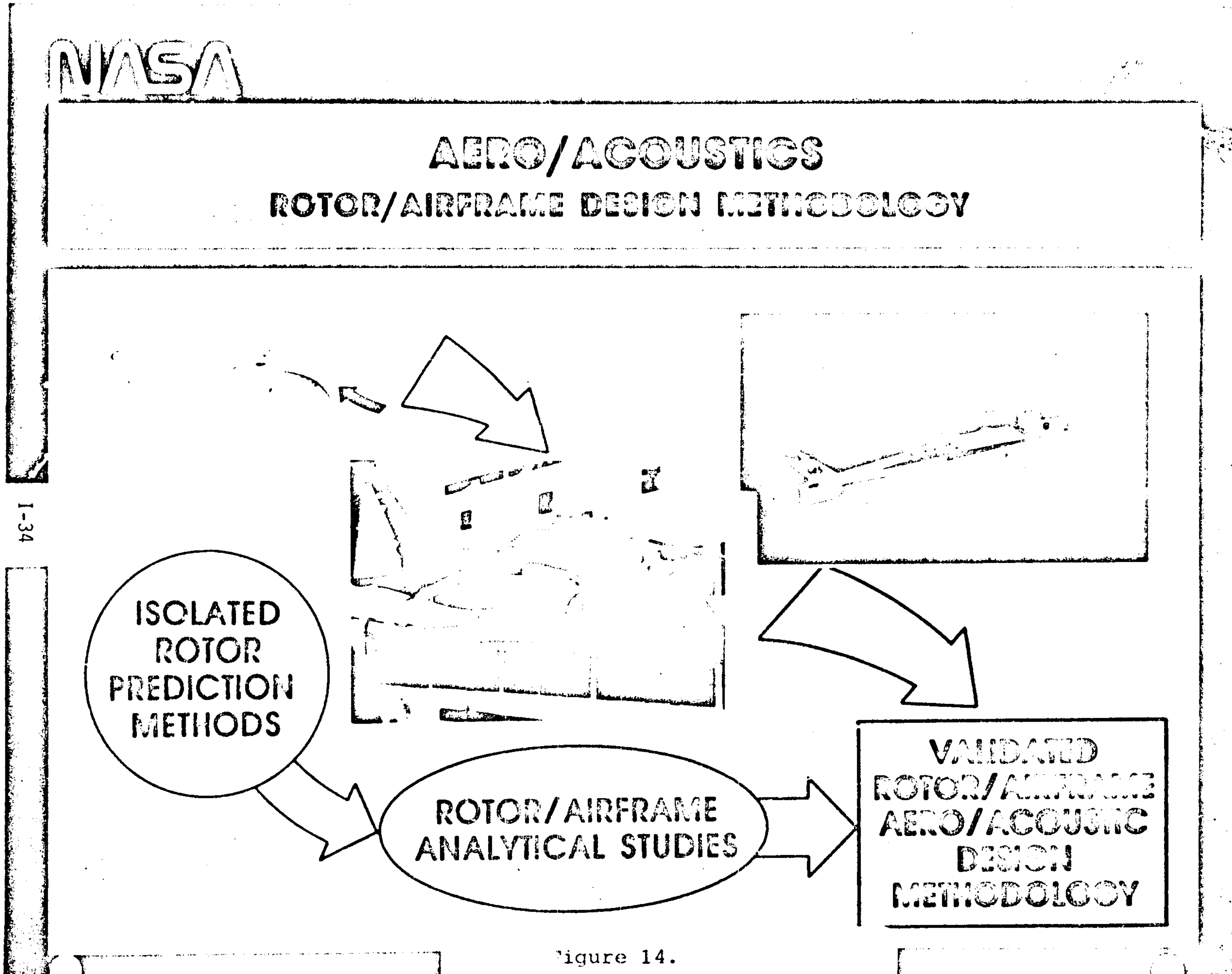
NASA
AERO/ACOUSTICS
ROTOR/AIRFRAME DESIGN METHODOLOGY
ISOLATED ROTOR PREDICTION METHODS
ROTOR/AIRFRAME ANALYTICAL STUDIES
VALIDATED ROTOR/AIRFRAME AERO/ACOUSTIC DESIGN METHODOLOGY

Figure 14.

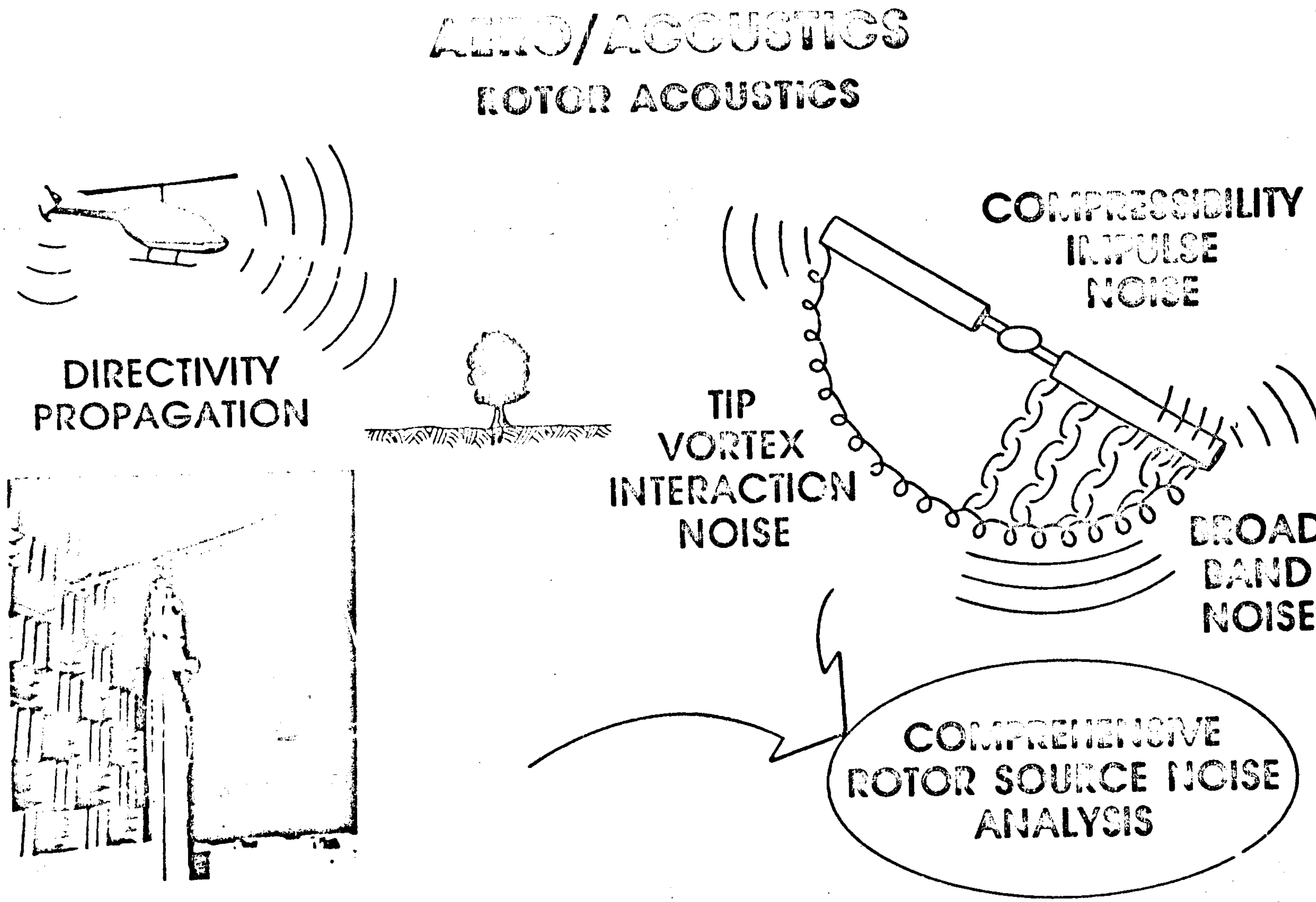
AERO/ACOUSTICS
ROTOR ACOUSTICS
DIRECTIVITY
PROPAGATION
COMPRESSIBILITY
IMPULSE
NOISE
TIP
VORTEX
INTERACTION
NOISE
BROAD
BAND
NOISE
COMPREHENSIVE
ROTOR SOURCE NOISE
ANALYSIS

Figure 15.

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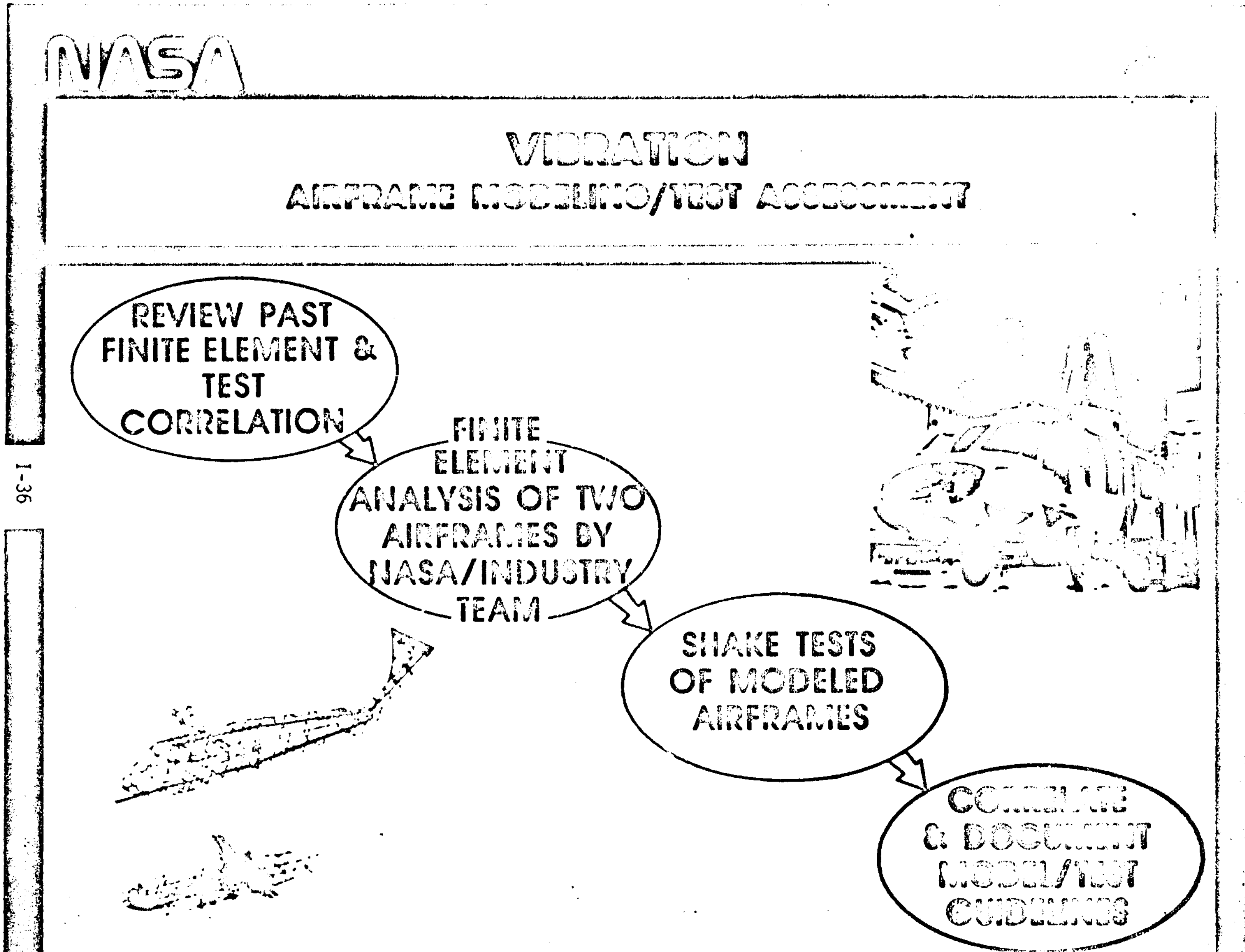

Figure 16.

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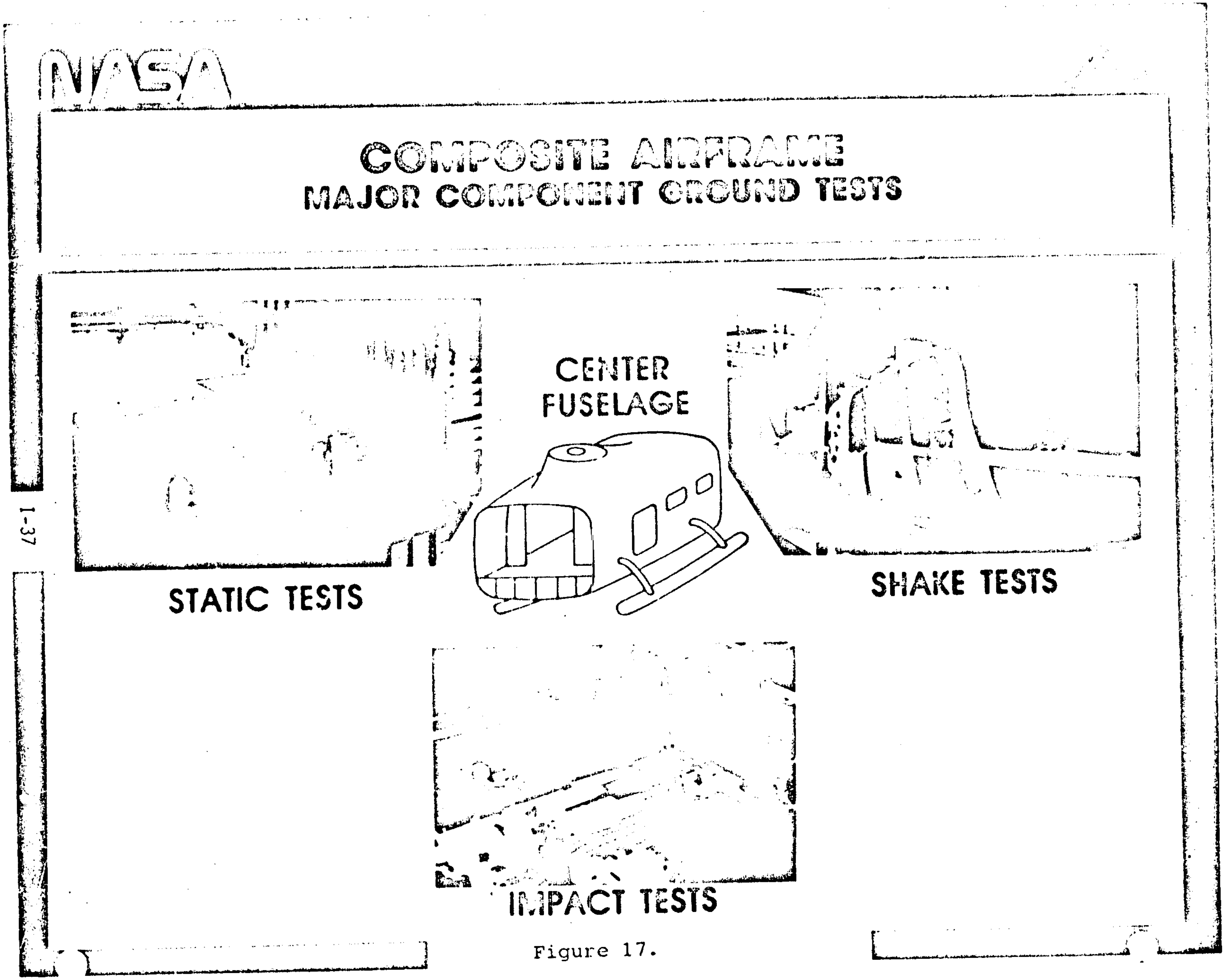

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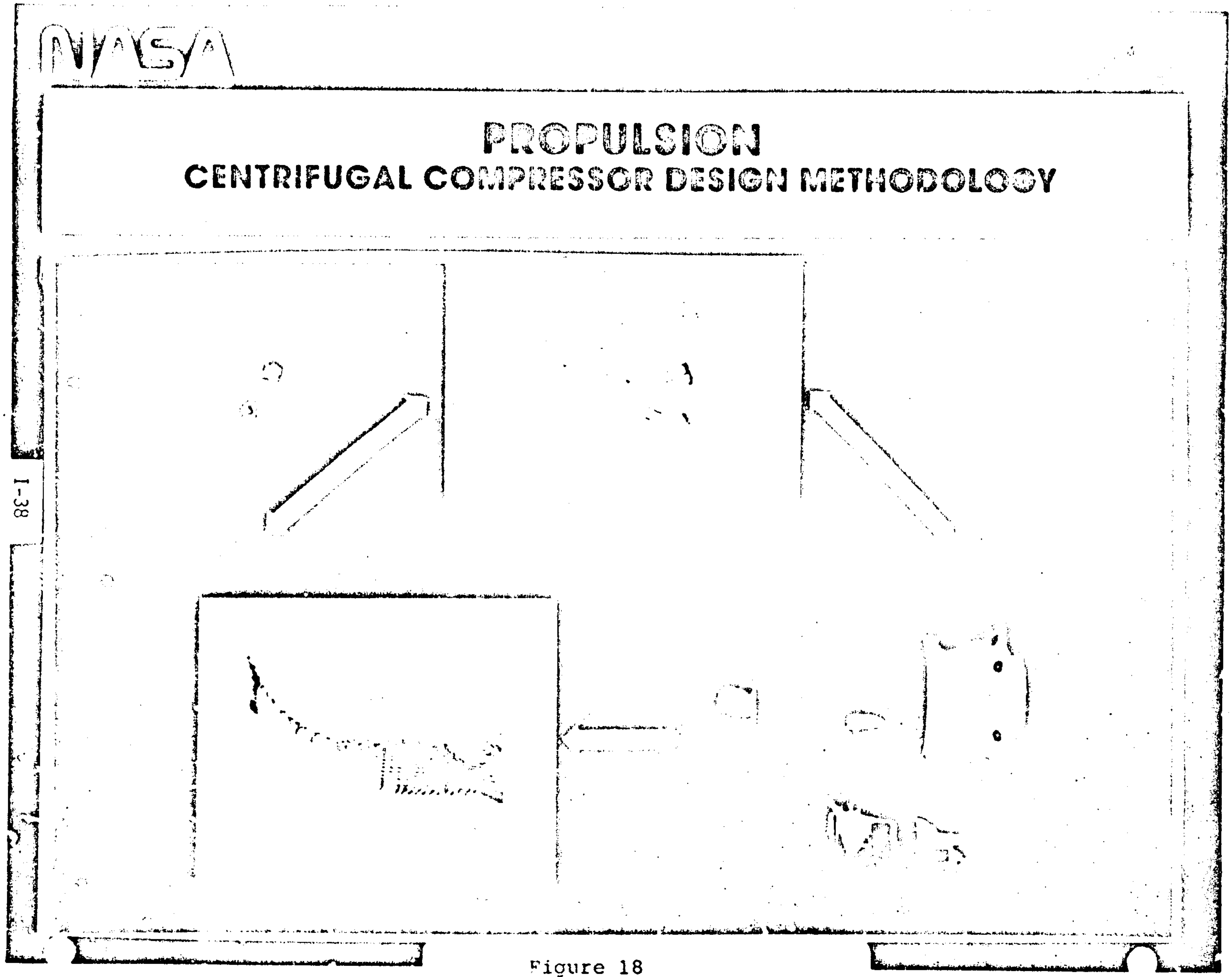


Figure 18

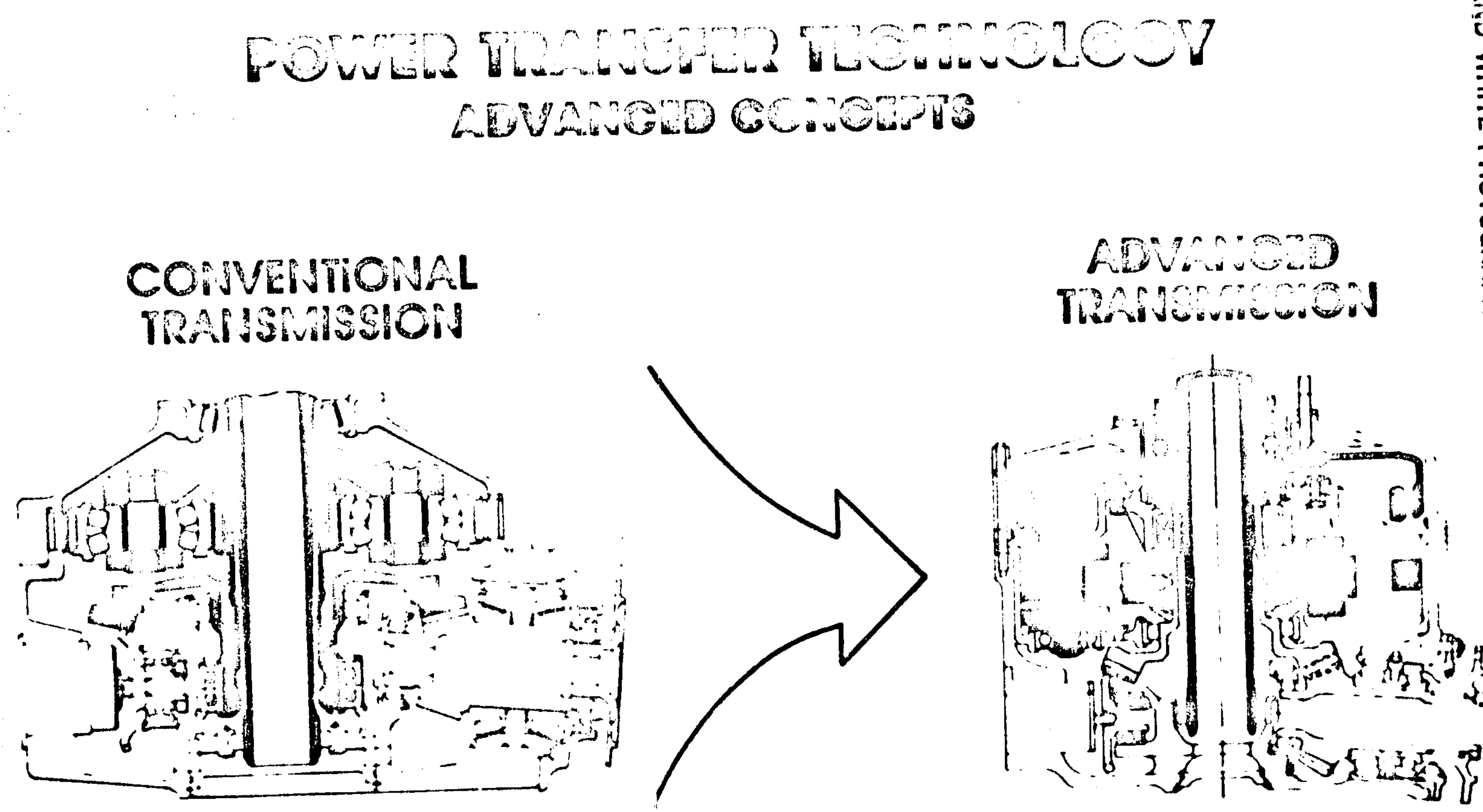

POWER TRANSFER TECHNOLOGY
ADVANCED CONCEPTS
CONVENTIONAL
TRANSMISSION
ADVANCED
TRANSMISSION

Figure 19.

COMPONENT INTEGRATION
POTENTIAL COMPOUND ROTORCRAFT PROPULSION SYSTEM

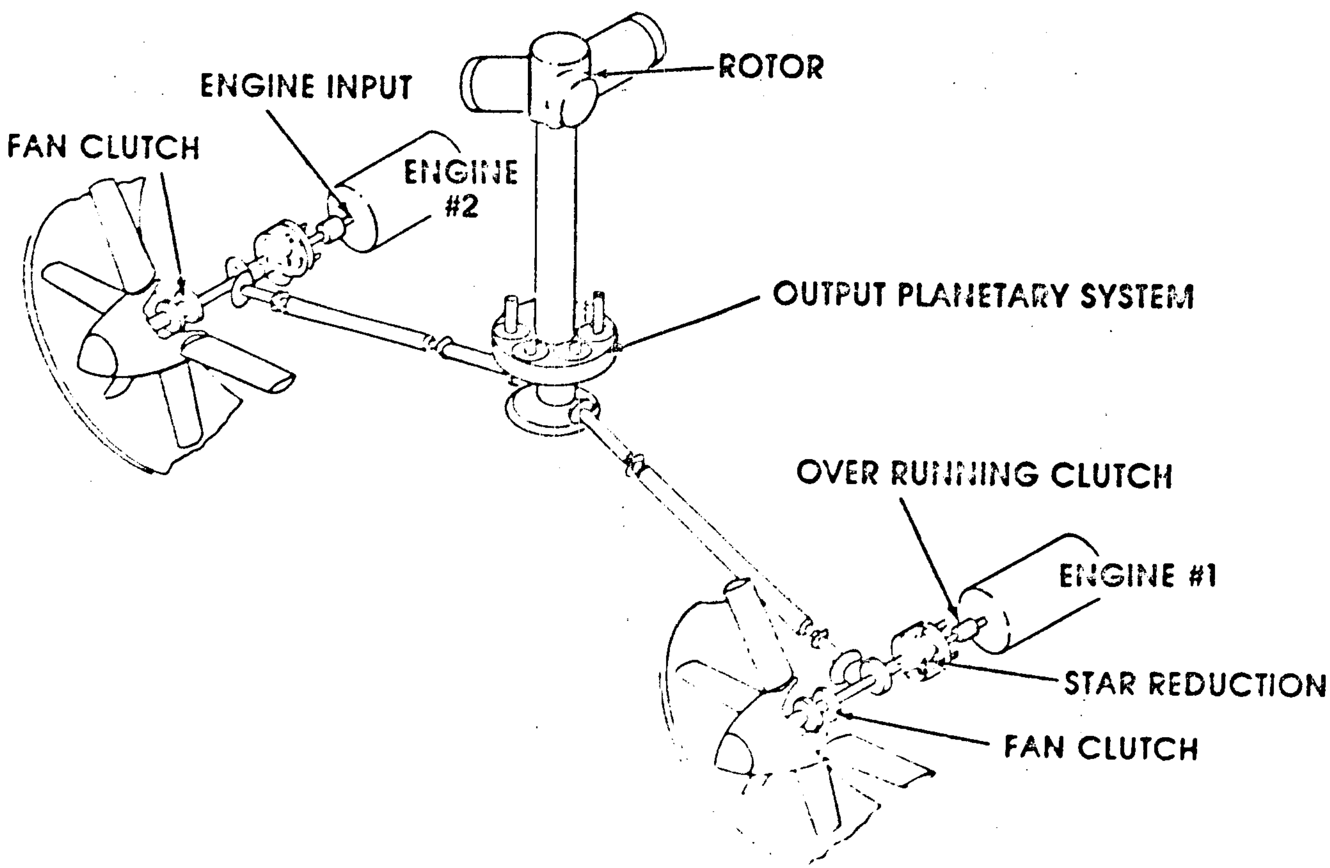
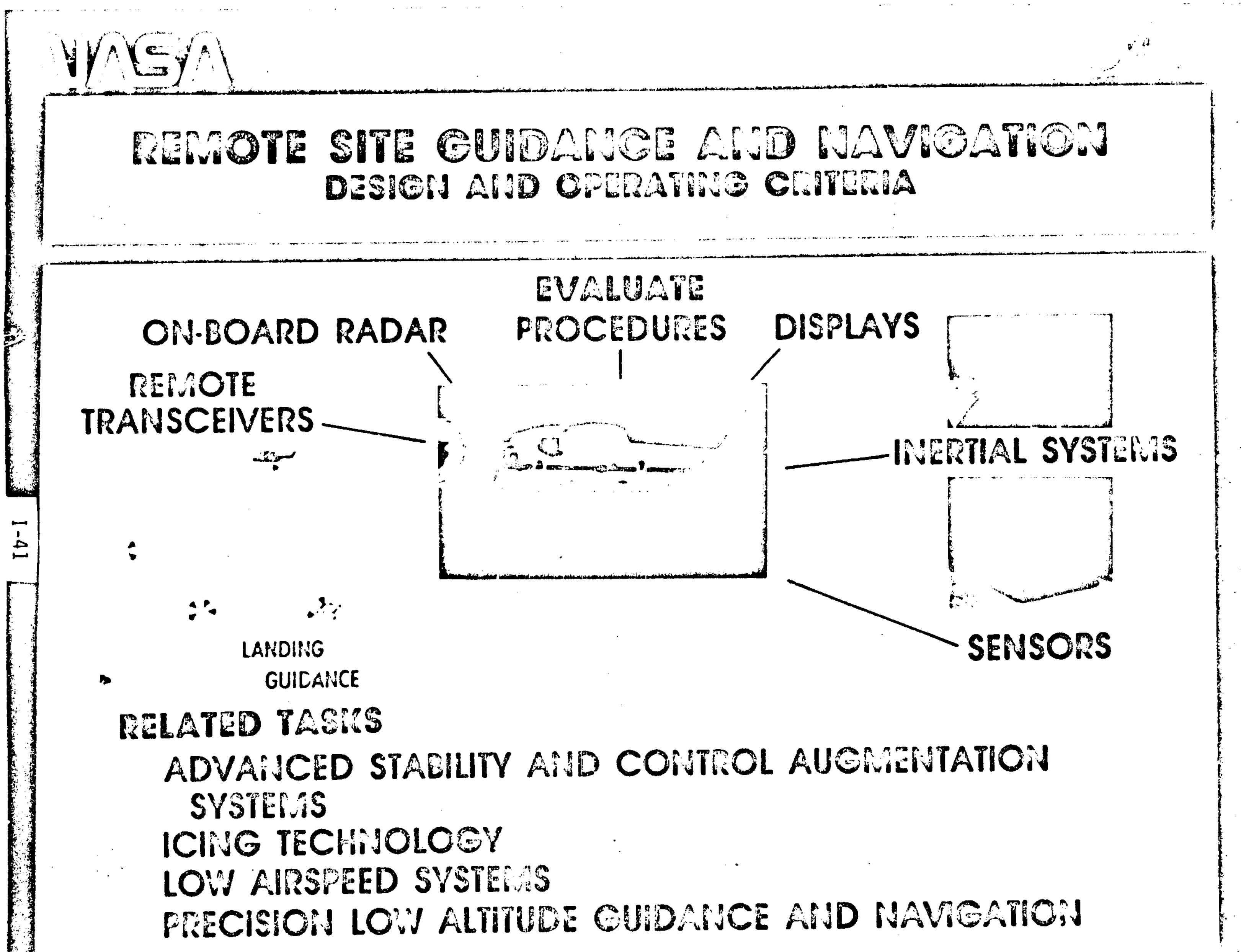


Figure 29.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REMOTE SITE GUIDANCE AND NAVIGATION
DESIGN AND OPERATING CRITERIA
EVALUATE PROCEDURES
ON-BOARD RADAR
DISPLAYS
REMOTE TRANSCEIVERS
INERTIAL SYSTEMS
LANDING GUIDANCE
SENSORS
RELATED TASKS
ADVANCED STABILITY AND CONTROL AUGMENTATION SYSTEMS
ICING TECHNOLOGY
LOW AIRSPEED SYSTEMS
PRECISION LOW ALTITUDE GUIDANCE AND NAVIGATION

Figure 21.

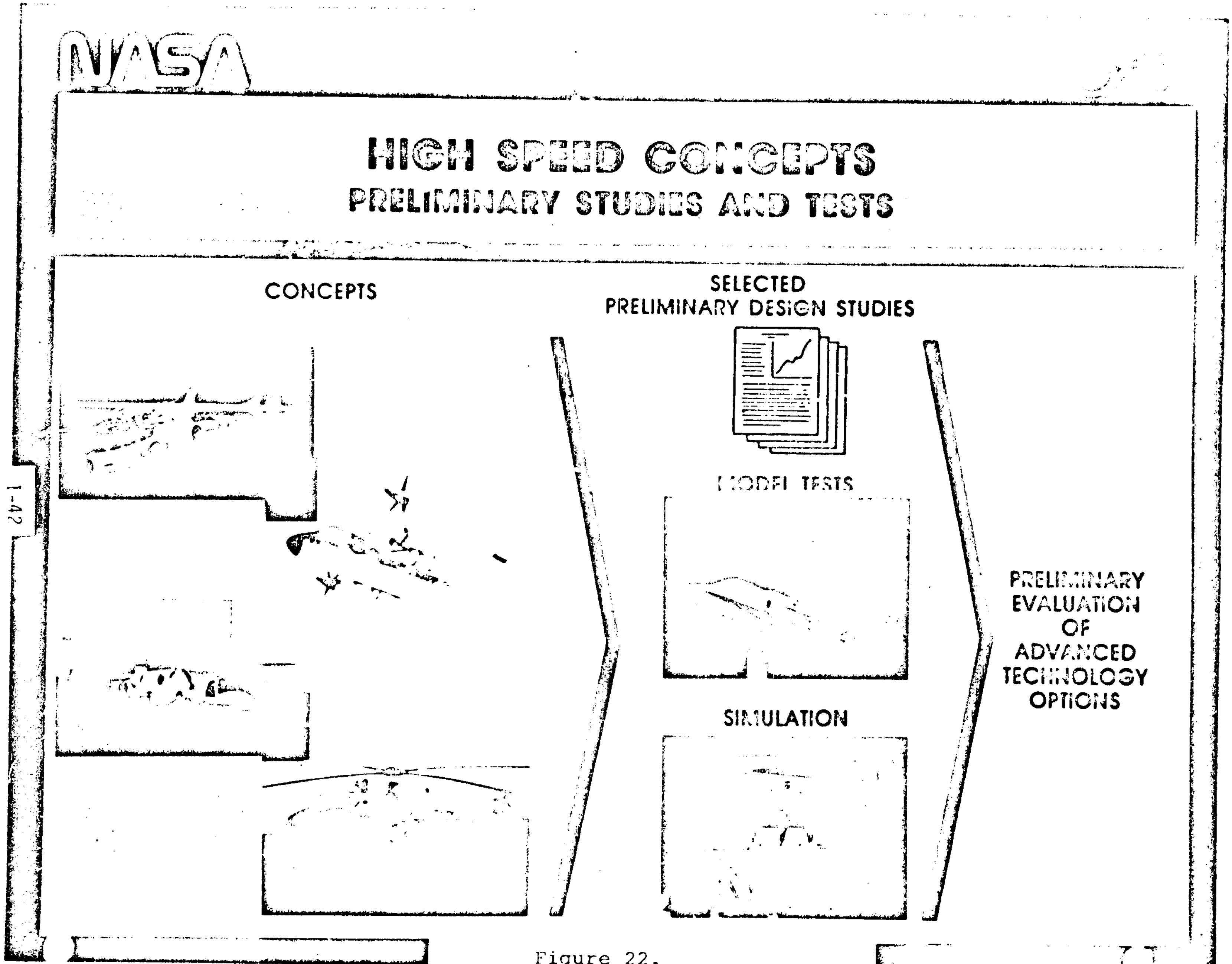
NASA
HIGH SPEED CONCEPTS
PRELIMINARY STUDIES AND TESTS
CONCEPTS
SELECTED
PRELIMINARY DESIGN STUDIES
MODEL TESTS
SIMULATION
PRELIMINARY
EVALUATION
OF
ADVANCED
TECHNOLOGY
OPTIONS

Figure 22.

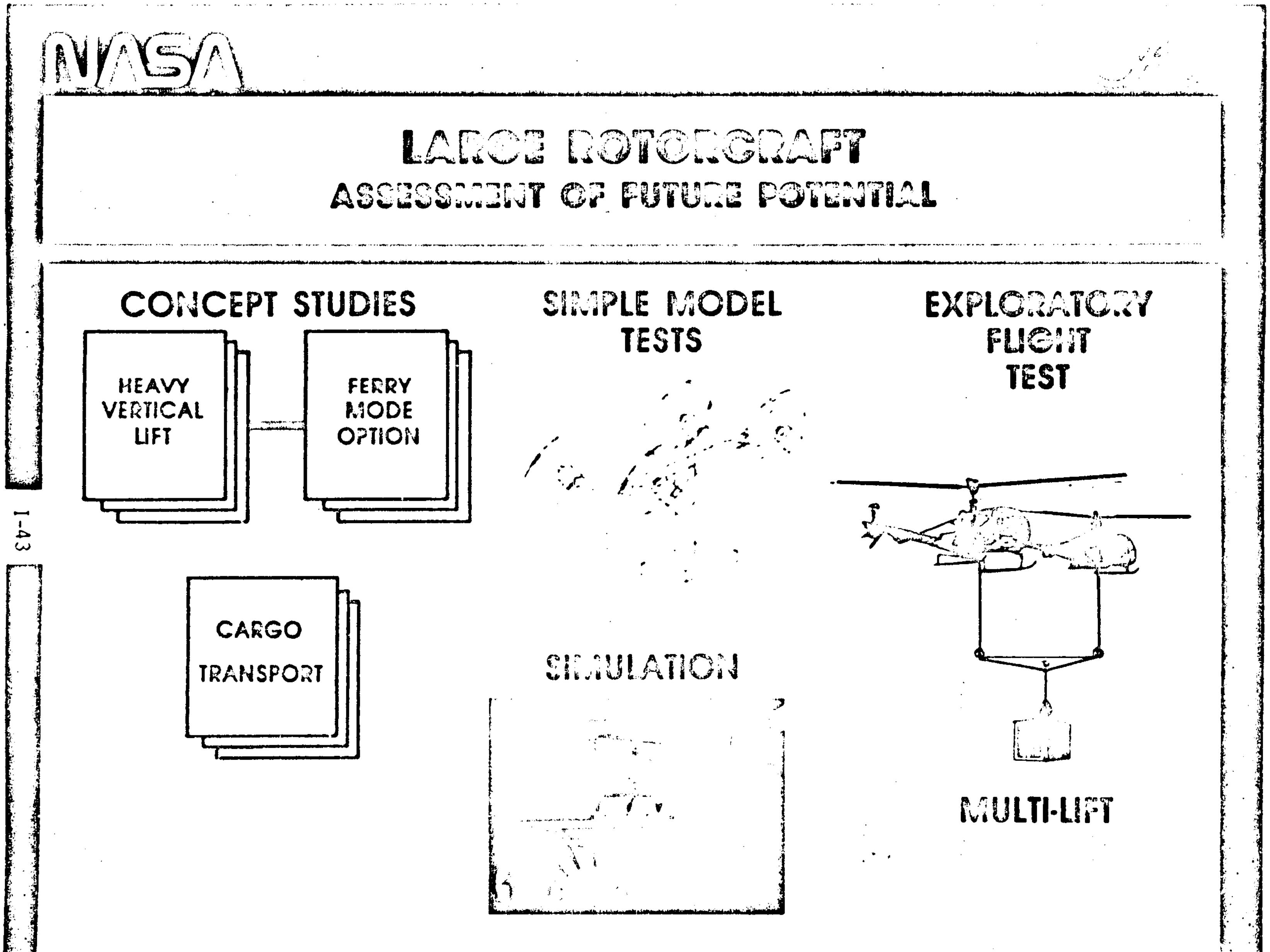
NASA
LARGE ROTORCRAFT
ASSESSMENT OF FUTURE POTENTIAL
CONCEPT STUDIES
HEAVY VERTICAL LIFT
FERRY MODE OPTION
CARGO TRANSPORT
SIMPLE MODEL TESTS
SIMULATION
EXPLORATORY FLIGHT TEST
MULTI-LIFT

Figure 23.

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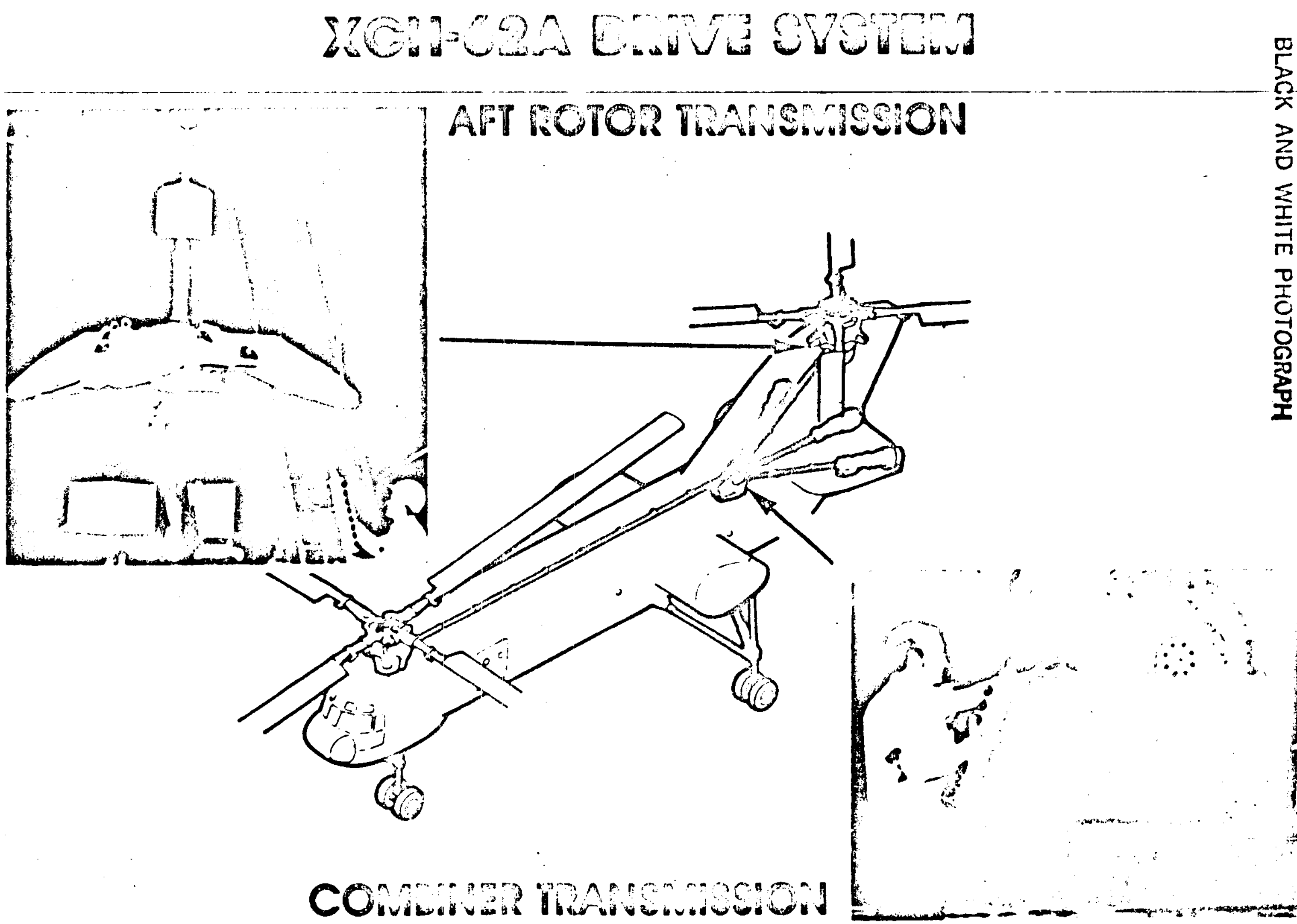

Figure 24.

TECHNICAL AREAS EMPHASIZED IN NASA RESEARCH

- THEORY AND DESIGN METHODOLOGY
  - ROTOR AERODYNAMICS
  - AEROELASTICITY
  - ACOUSTICS
  - FLYING QUALITIES
  - PASSENGER COMFORT
  - PROPULSION SYSTEMS

- VALIDATION OF METHODOLOGY
  - WIND TUNNEL
  - FLIGHT EXPERIMENTS

- VEHICLE CONFIGURATION STUDIES TO IDENTIFY MOST PROMISING NEW CONCEPTS

  FOLLOWED BY PROOF-OF-CONCEPT FLIGHT DEMONSTRATION OF THE MOST ATTRACTIVE CONFIGURATIONS

NASA

Figure 25.

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ADVANCED ROTORCRAFT TECHNOLOGY

PROGRAM ELEMENTS

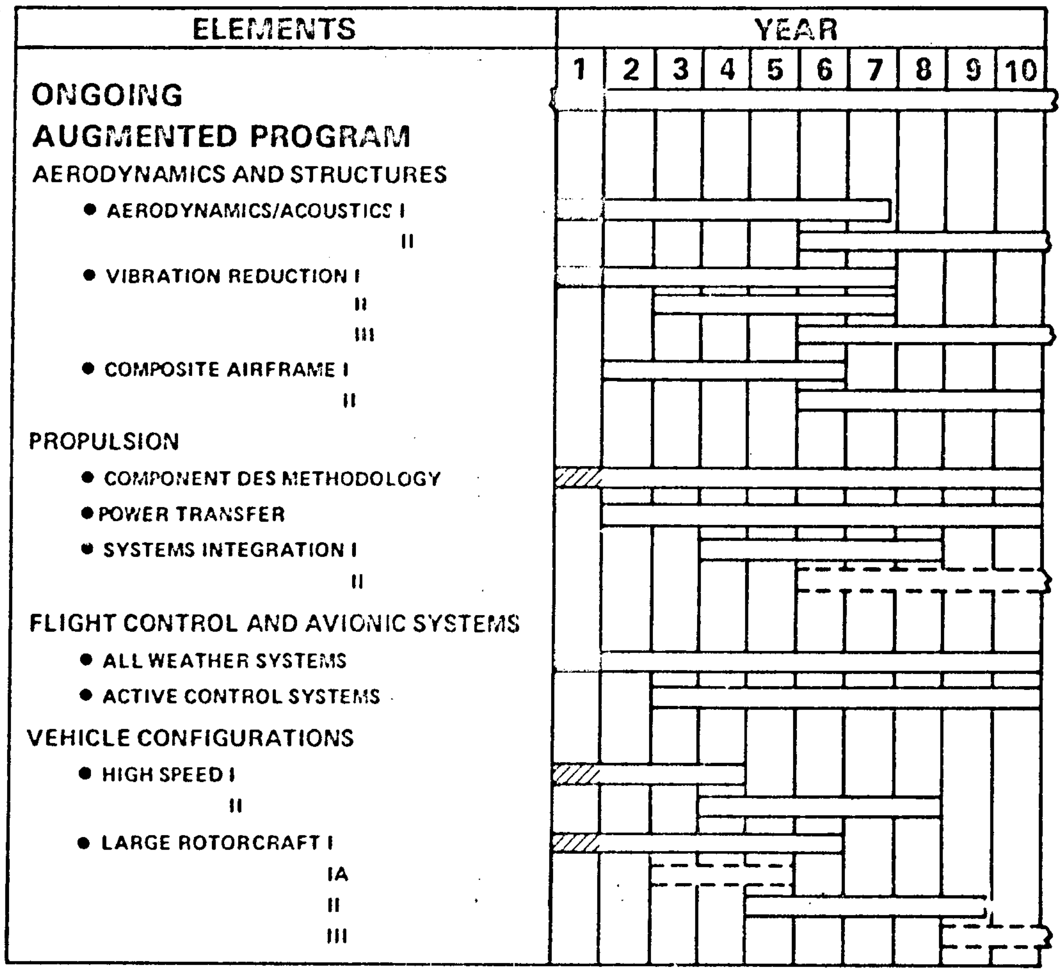

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Figure 26.

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ROTORCRAFT FUNDING

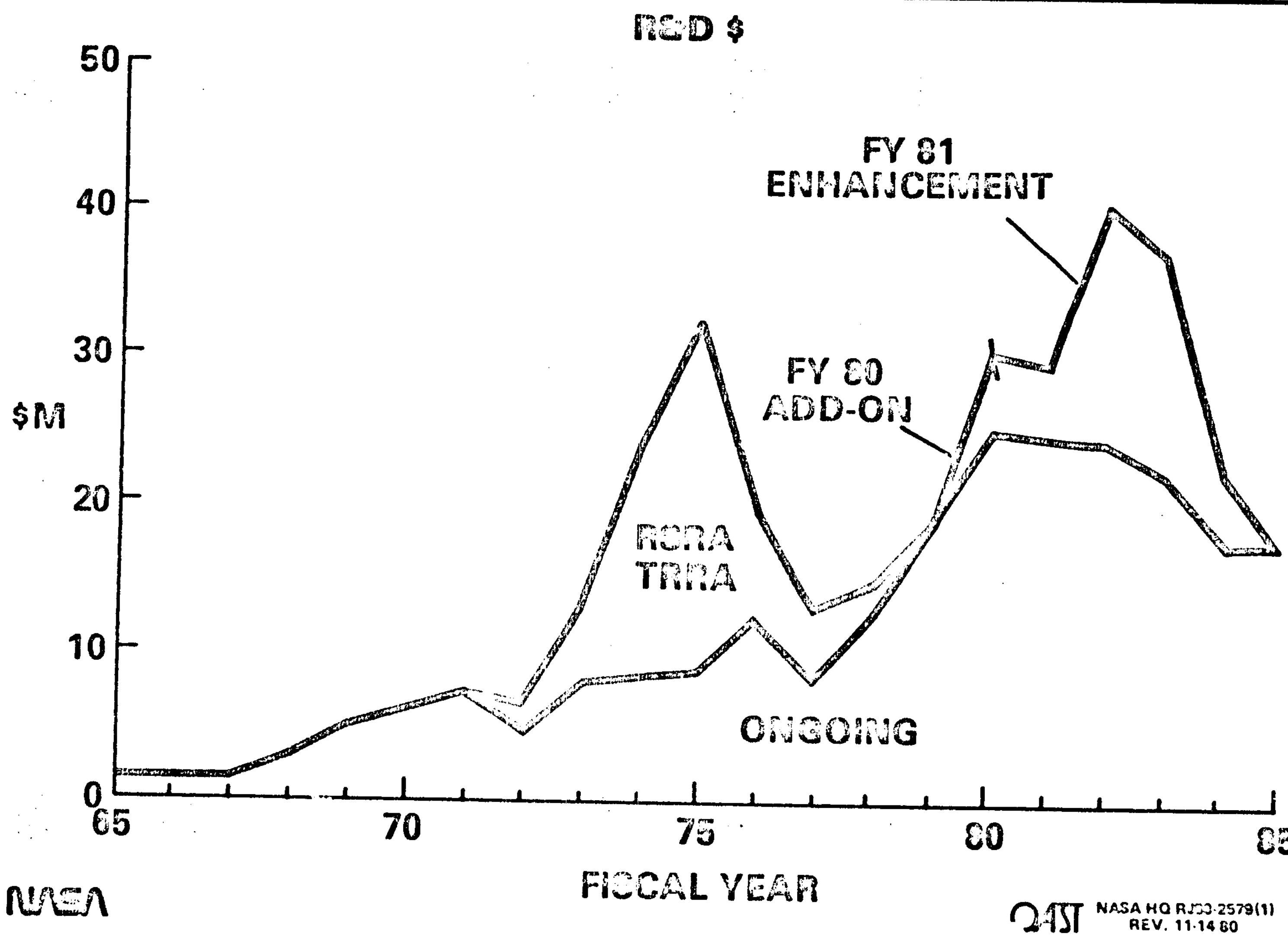

Figure 27.

FUTURE DIRECTIONS AND OPPORTUNITIES IN ROTORCRAFT (1990's)

CIVIL POTENTIAL

- QUIET, JET-SMOOTH, ALL-WEATHER ROTORCRAFT IN EXPANDED EXECUTIVE, COMMERCIAL, UTILITY, AND PUBLIC SERVICE ROLES
- TRANSPORT ROLE
  - CAPABILITY INCREASING FROM 60- TO 200- PASSENGER VEHICLES ON SHORT-HAUL ROUTES
  - MAJOR REDUCTIONS IN SEAT-MILE COSTS
  - TRIP TIME MINIMIZED BY AVOIDANCE OF GROUND-TRANSIT BY USING CLOSE-IN HELIPORTS
  - RELIEF OF HUB AIRPORT CONGESTION
- CARGO ROLE
  - PAYLOADS INCREASING TO 75 TONS
  - HYBRID SYSTEMS (ROTORS & BOUYANT HULL) HAVE POTENTIAL OF 150- TO 500- TON PAYLOADS
  - MAJOR IMPACT ON WORLD INDUSTRIAL SITING AND DISTRIBUTION SYSTEM

NASA

Figure 28

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5 14 80

THE PRINSENDAM STORY

by

Richard L. Schoel
Commander, U.S. Coast Guard
Search and Rescue Branch
Seventeenth Coast Guard District

The radiomen of COMMSTA SAN FRANCISCO were going through their normal routine, when at 1:00 am on Saturday the 4th of October 1980, the radio static was broken with the distress call of the MV PRINSENDAM, stating that her engine room was on fire, that the engine room had been flooded with carbon dioxide and that there were 329 passengers and 190 crew on board. This distress call was to set the stage for the most miraculous air/sea rescue of modern time.

The MV PRINSENDAM was a 427 foot luxury liner worth approximately 50 million dollars. She had a 62 foot breadth, 19 foot draft, a gross register of 9.00 tons, and a cruising speed of 19 knots. Her hull was stabilizer equipped and she contained a swimming pool, restaurant, three bars, a cinema, shopping center and 209 staterooms. The PRINSENDAM's personnel complement, at the time, consisted of 164 Indonesian crew members, 26 Dutch officers and 329 passengers, for a total of 519.

Owned by the Holland America Lines of the Netherlands, she was on an extensive cruise from Vancouver, B.C. up the Inside Passage of Southeast Alaska to Ketchikan and Glacier Bay. From there the PRINSENDAM was to have traveled to Japan, China and the Republic of Singapore.

The position of the PRINSENDAM's distress was 57-38 degrees North and 140-25 degrees West, which when triangulated, placed her approximately 429 miles East of Kodiak, 330 miles Southeast of Valdez, 129 miles South

Commander Schoel was the featured speaker at the wrap-up luncheon of the HAA/NASA Advance Rotorcraft Technology Workshop on December 5, 1980. He directed the rescue of 500 passengers from the sinking cruise ship Prinsendam in the Gulf of Alaska on October 4, 1980.

of Yakutat and 195 miles West of Sitka. With the initial distress call received at 1:08 am, NORPACSARCOORD in Juneau, Alaska was alerted as SMC and began to execute the case. Within 40 minutes the following units were activated and responding:

(CGC BOUTWELL) The CGC BOUTWELL departed from Juneau where she was moored for participation in the city's centennial celebration.

(CGC WOODRUSH) The CGC WOODRUSH departed from Sitka, enroute the scene.

(CGC MELLON) CGC MELLON was diverted to the scene as she was underway enroute Alaska for a fisheries patrol.

(HH-3F Helo) COGARD AIRSTA SITKA, which provided two H-3 helicopters and:

(C-130) Two HC-130 fixed-wing aircraft.

(CH-46 Helo) RCC VICTORIA which provided two CG-45 helicopters and:

(Can. Buffalo) Two Canadian buffaloes, and one Argus fixed-wing aircraft, ELMENDORF AIR FORCE BASE, which provided one H-3 helicopter and one HC-130 refueler and RCC KODIAK, which provided additional communications support. Thirteen aircraft, rotary and fixed wing, three Coast Guard Cutters and three commercial vessels became involved by the mission's completion. One of the most important commercial vessels involved was the Tanker Vessel WILLIAMSBURGH.

The WILLIAMSBURGH is a 1,000 foot super tanker owned by the Wilmington Trust Company of Wilmington, Delaware. At the time of the distress she was laden with Alaskan Crude Oil, obtained from the Port of Valdez. Enroute a port in Texas, the WILLIAMSBURGH's position was relayed to NORPACSARCOORD from RCC VICTORIA, B.C., as she was not on the initial

SURPIC request. Approximately 5 hours away from the scene, the WILLIAMSBURGH proceeded at 17 knots to serve as a staging platform from which to execute the rescue. Characteristics which made her ideally suited, under the circumstances, were her 65 foot draft, which allowed her to ride low in the water and, consequently, increased her stability, a helo pad, room to house all 519 survivors, should the need arise and availability.

By 4:00 am, a Kodiak based C-130 was on scene, established OSC, and had commenced giving a continuous flow of information concerning the case. The engine room fire had spread forward and upward reaching the dining room by 5:12 am. With this spreading came the elimination of all power, water pressure and consequently firefighting capabilities.

Abandoning the PRINSENDAM in 6 lifeboats, 1 covered motor launch and 4 liferafts, with 18-30 passengers each, the crew and passengers executed a safe and orderly departure, commencing at 5:12 am. Within moments the tiny flotilla was launched into 5-10 foot seas, 10-15 knot winds and deteriorating weather conditions.

Remarkably, not one casualty or major injury was reported, though one covered motor launch and several liferafts got hung up in the ship's rigging. A 50 man firefighting crew remained on board the PRINSENDAM and continued fighting the fire with personnel and firefighting equipment lowered to her decks from a Coast Guard H-3 helicopter. They were to remain on board until 1:45 pm, at which time the CGC BOUTWELL arrived on scene. At that time, a request for immediate removal was dispatched from the firefighting crew. By 4:14 pm, all had been removed to the safety of the CGC BOUTWELL.

The weather on scene had deteriorated throughout the day to 25-35 foot seas, scattered showers and 15-20 knot winds. With the onset of darkness, transfer operations from the lifeboats and rafts were stepped up considerably. By this time, there were 5-6 helicopters involved airlifting survivors to safety. Hoisting operations progressed to the point of 8-12 survivors being taken aboard each helicopter, individually before returning to the T/V WILLIAMSBURGH or CGC BOUTWELL.

By 4:30 pm, 1 lifeboat of survivors remained to be transferred. Additional transfer of survivors took place via small boat from the CCC BOUTWELL. Upon disembarking from the helicopters, on board the WILLIAMSBURGH or CGC BOUTWELL, survivors received immediate medical attention, blankets and food.

By 6:16 pm, all survivors were believed to be accounted for either on board the CGC BOUTWELL, T/V WILLIAMSBURGH or in the town of Sitka. At this time, the M/V's PORTLAND and SOHIO INTREPID were released from the case and the T/V WILLIAMSBURGH proceeded enroute Valdez, to off load survivors.

The CGC BOUTWELL, meanwhile, remained on scene awaiting the arrival of CGC MELLON and further orders. A review of resources used during the case revealed two U.S. Air Force Pararescuemen unaccounted for. Known to have been lowered into a lifeboat containing 18-20 survivors at 3:45 pm, they could not be located on board the T/V WILLIAMSBURGH, CGC BOUTWELL nor at Sitka. The CGC BOUTWELL immediately returned to the scene, established datum and commenced an expanding square search pattern in the hopes of finding the missing lifeboat. Confirmation that one lifeboat was definitely unaccounted for came from the M/V SOHIO INTREPID in a message stating that the missing lifeboat was last seen when a U.S. Air Force helicopter was forced to make an emergency landing on her deck. During the excitement and worsening weather conditions, the lifeboat was evidently overloaded. At 1:01 am, 5 October, the missing lifeboat was found with the two Pararescuemen and 18 survivors on board. All were in excellent condition, considering the circumstances, and taken on board for the 9 1/2 hour trip to Sitka.

At 2:30 pm, 5 October, the CGC BOUTWELL arrived in Crescent Harbor, Sitka, Alaska and shuttled survivors ashore on the M/V St. Nicholaus. Once ashore, survivors were taken by bus to the Sheffield House Hotel to await comparison of survivor manifests with the master manifest held by the Holland America Lines and transport home.

The T/V WILLIAMSBURGH, meanwhile, arrived in Valdez at 6:10 pm, 5 October, disembarked her survivors, compared manifests and prepared to depart for a port in Texas. A final manifest of survivors indicated that 62 were airlifted to Sitka during the case, 87 were taken on board the CGC BOUTWELL and 379 were taken on board the T/V WILLIAMSBURGH for a total of 519.

A staging area was set up at Yakutat for logistic, medical and aircraft support. With aircraft remaining on scene to the maximum, many survivors were brought back to Yakutat at the duration of each sortie to conserve fuel. They were then transported to Sitka. Once in Sitka, the survivors were to await the conclusion of the mission before going home.

With the rescue of all survivors, attention was turned to the "salvage" end of the operation. During the 5th of October, the CGC's MELLON and WOODRUSH remained on scene checking out and marking or sinking all life-boats and rafts deployed during the mission to ensure accountability.

On 6 October, the PRINSENDAM was a burning hulk drifting in a northwesterly direction at approximately 2 knots. The CGC MELLON and an H-3 helicopter remained nearby awaiting the arrival of the ocean-going tug COMMODORE STRAITS, from Vancouver, B.C. The COMMODORE STRAITS was to tow the PRINSENDAM off the shore of Alaska a distance of 50 miles or more, at the request of the U.S. Coast Guard, while enroute the Port of Portland, Oregon.

At 1:30 pm, 6 October, heavy smoke poured from the PRINSENDAM, due to a simultaneous ignition of 15 rolls of carpeting and a liferaft, stored on her upper deck. By 5:30 pm, the smoke had subsided and the COMMODORE

STRAITS had arrived on scene.

The PRINSENDAM's deck plan consisted of a B-Deck, which was indicated by the lowest row of port holes, an A-Deck, Main Deck, Promenade Deck, Bridge Deck and a Sun Deck.

At 11:15 am on 7 October, a 9 man firefighting assessment and rigging team was put on board the PRINSENDAM to rig her for towing and assess the damage. The PRINSENDAM was taken under tow at 2:30 pm.

The port side promenade Deck was smoking at three lifeboat stations with fire below. The upper cabins were not burned as extensively as the starboard side, but were in danger. The Bridge Deck was burning significantly. Various "hot spots" could be seen as could the direction the fire was spreading, due to the port holes bursting as the fire progressed. The PRINSENDAM was now veering slightly as she was being towed by her anchor chain. Speed of advance of the COMMODORE STRAITS was 5-6 knots, at this time.

By the 9th of October, the bridge area of the PRINSENDAM had been burned to the point of total collapse in certain areas. Damage was extensive by this time as the fire had ravaged most of the ship during the previous three days. The starboard side revealed smoke coming from the main stairway and fan room under the bridge, with most upper decks buckled and interior stanchions on the Promenade Deck buckling up to 9 inches.

The fire had gutted the bridge deck and cabins on the Promenade Deck, starboard side. Extensive heat caused exterior paint to blister and, in some cases, catch on fire. She was listing approximately 15 degrees to starboard by the 7th of October and the Bridge Deck, Promenade Deck and Main Deck aft were completely burned out by then.

By 10:30 am, 10 October, the PRINSENDAM could no longer be towed straight ahead. She was veering extensively while being towed, reducing the speed of advance of the COMMODORE STRAITS to 2-3 knots.

The PRINSENDAM was listing 30-35 degrees to starboard and was down by the bow on the morning of 10 October. Port holes on the B and A Decks were all broken out by the fire and water was flowing in and out at will. Periodically, the water would reach the Main Deck and enter the interior of the ship by this means. She was rolling from 20 degrees port to 35 degrees starboard, sustaining an 11 second period of roll on her starboard side.

By first light on 11 October, the PRINSENDAM was listing 40-45 degrees to starboard and reducing the speed of advance of the COMMODORE STRAITS to 2-3 knots. At 8:30 am, the PRINSENDAM rolled on her starboard side and sank at 8:33 am, in 1473 fathoms of water.

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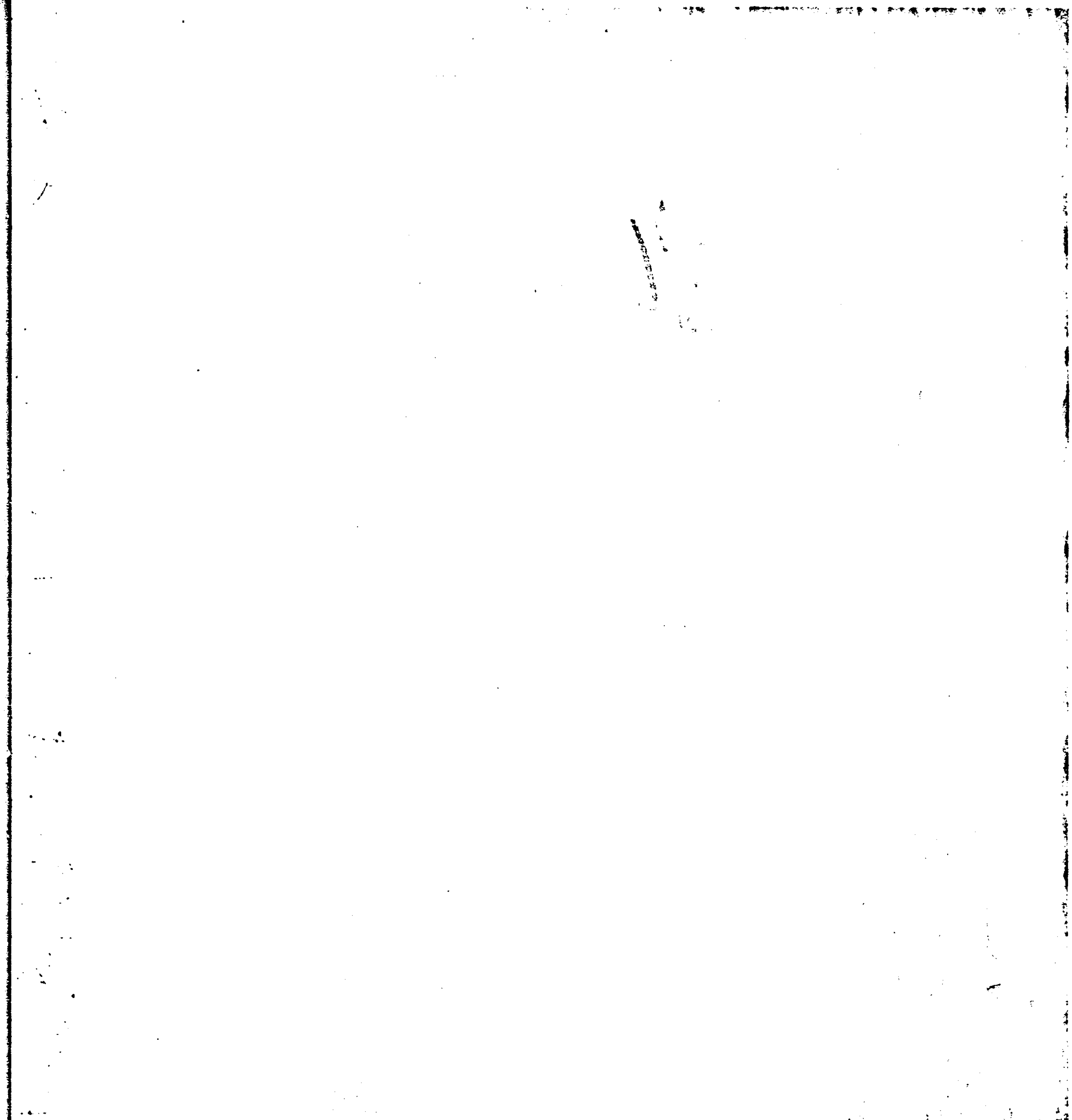

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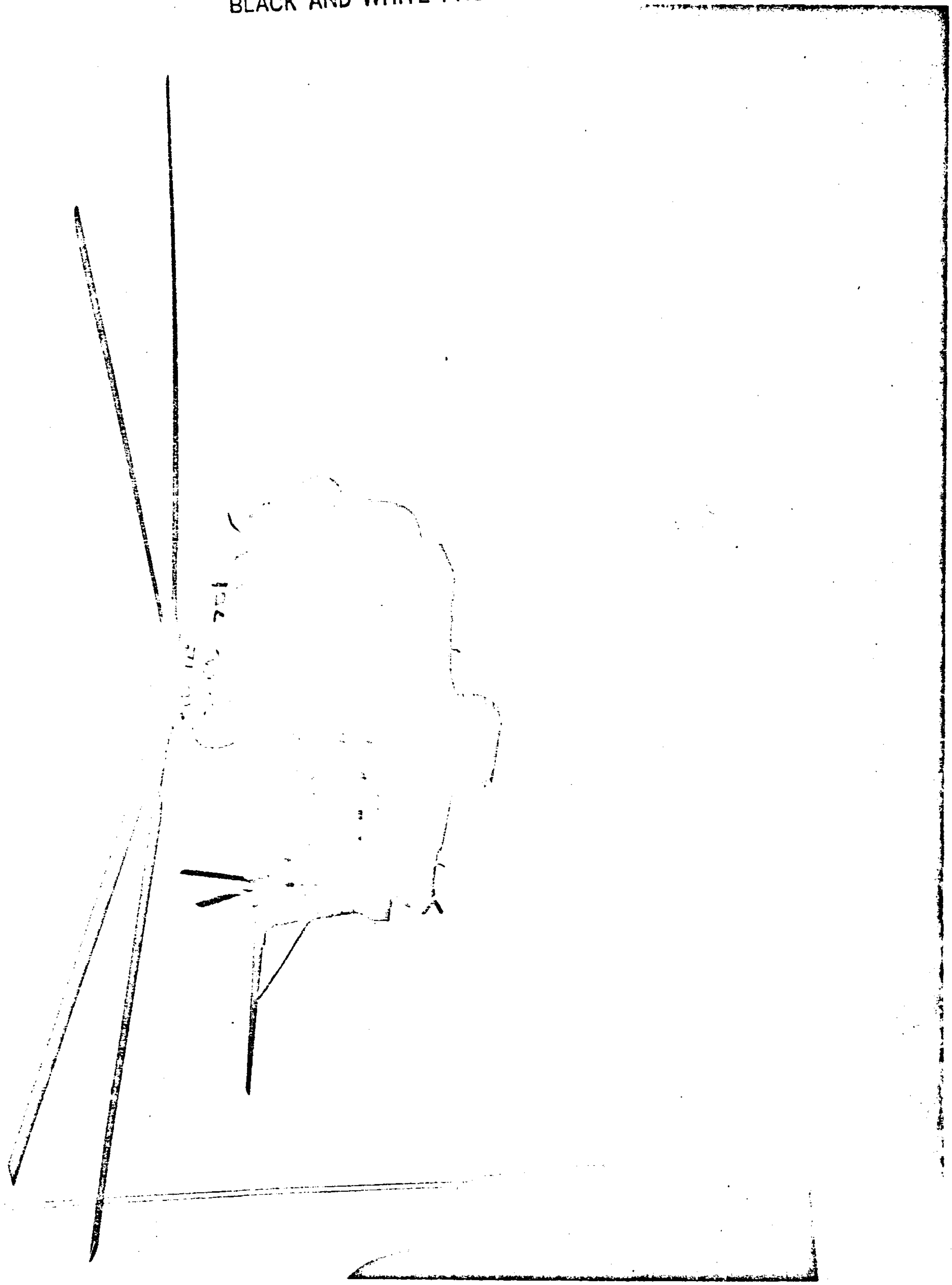

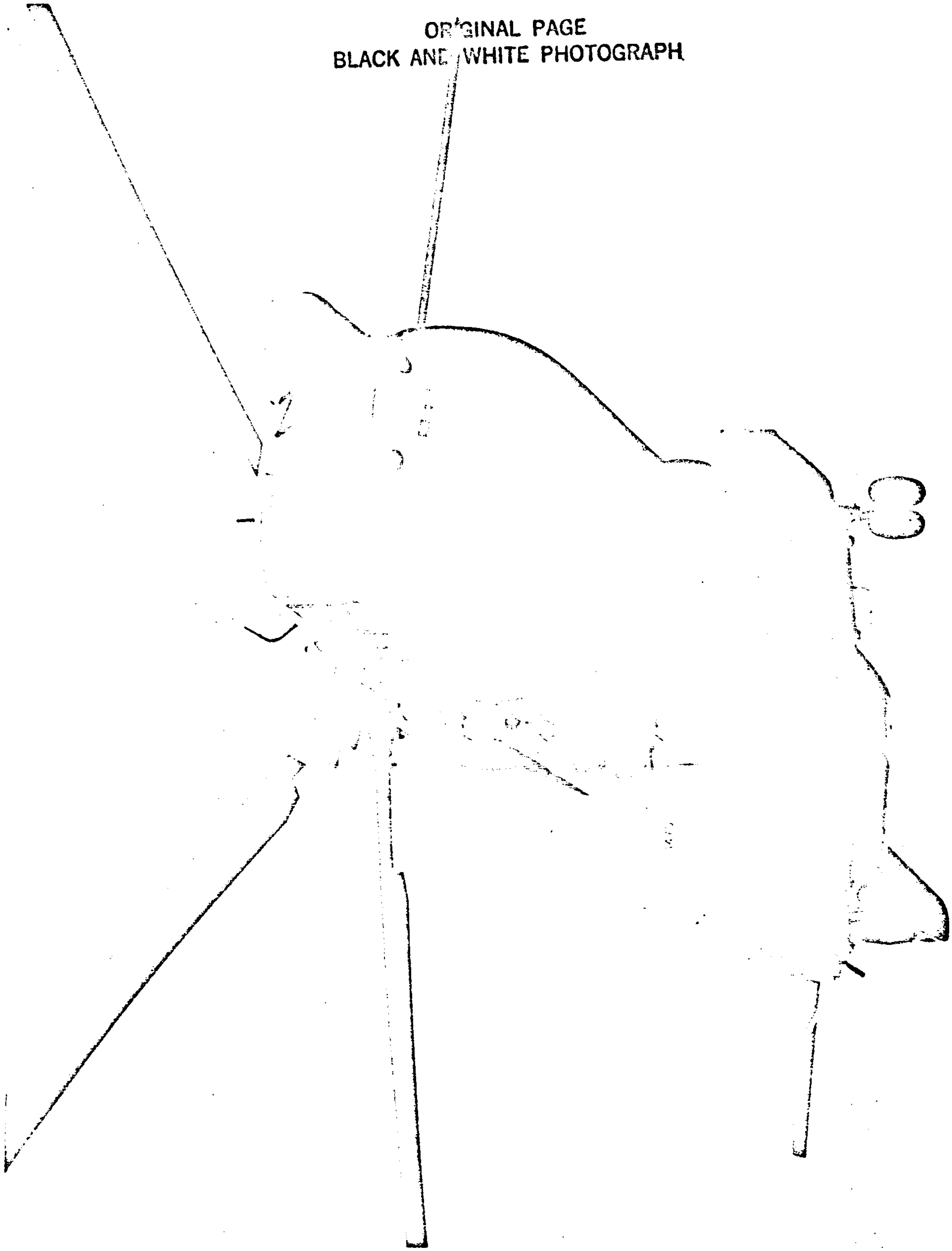

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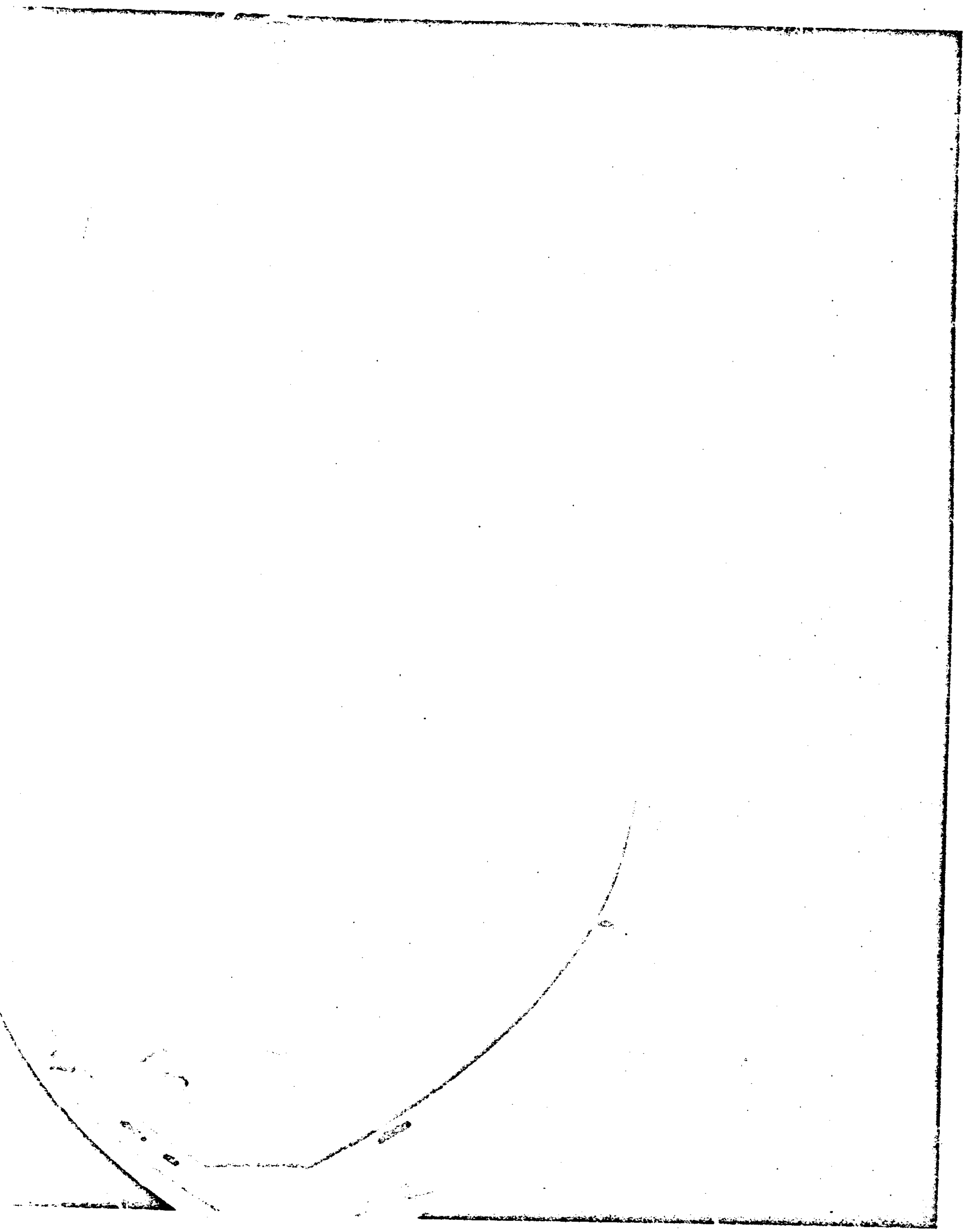

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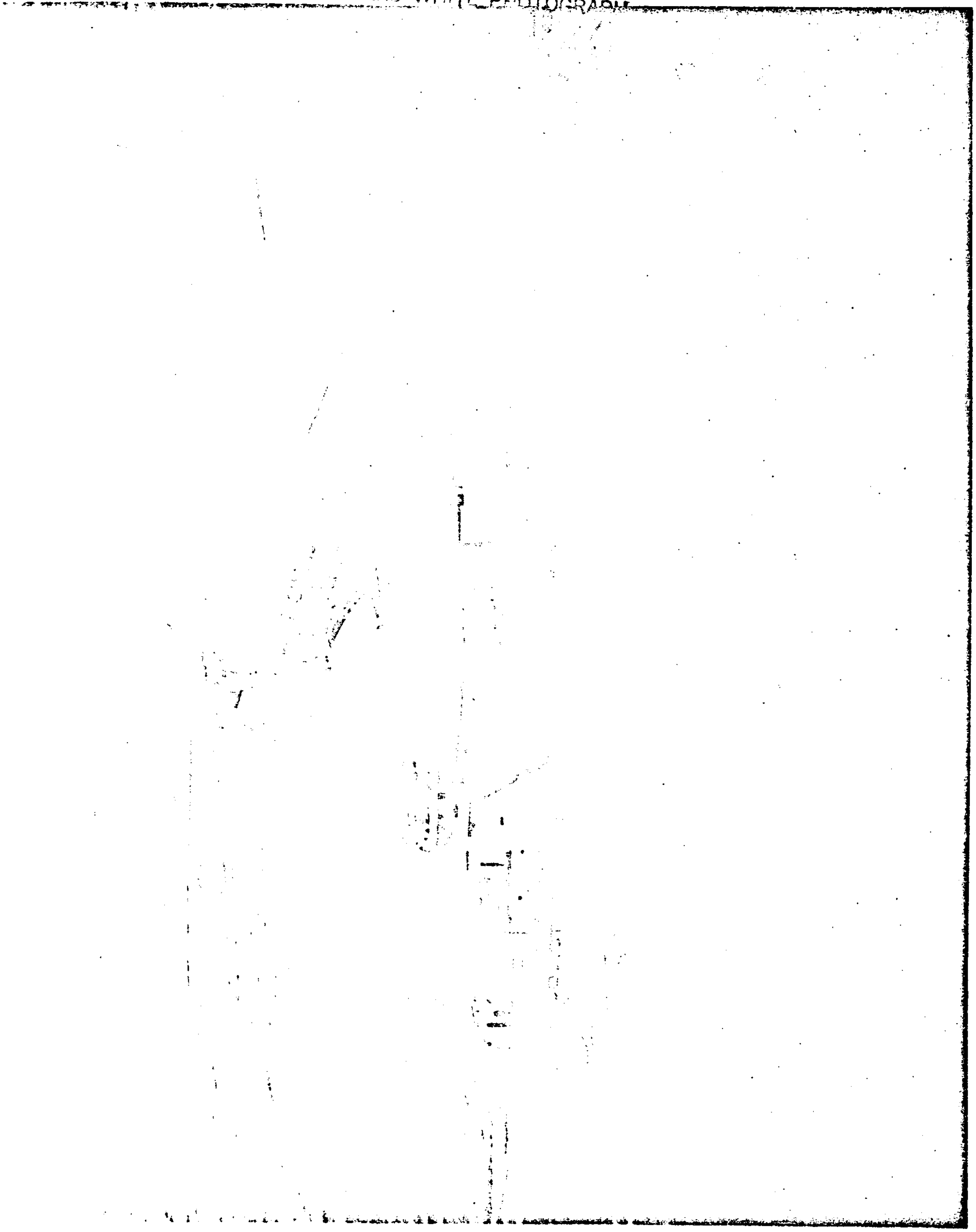

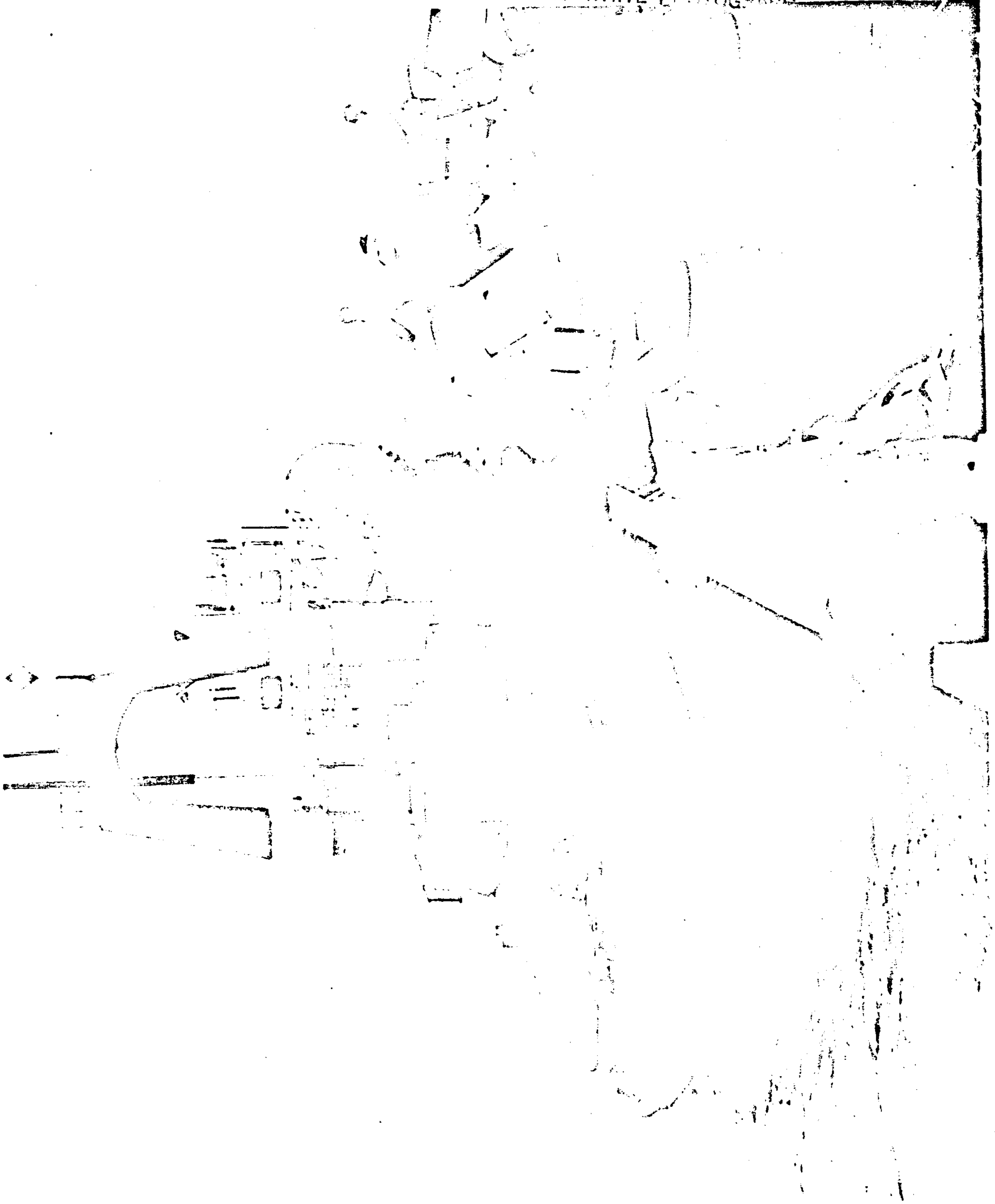

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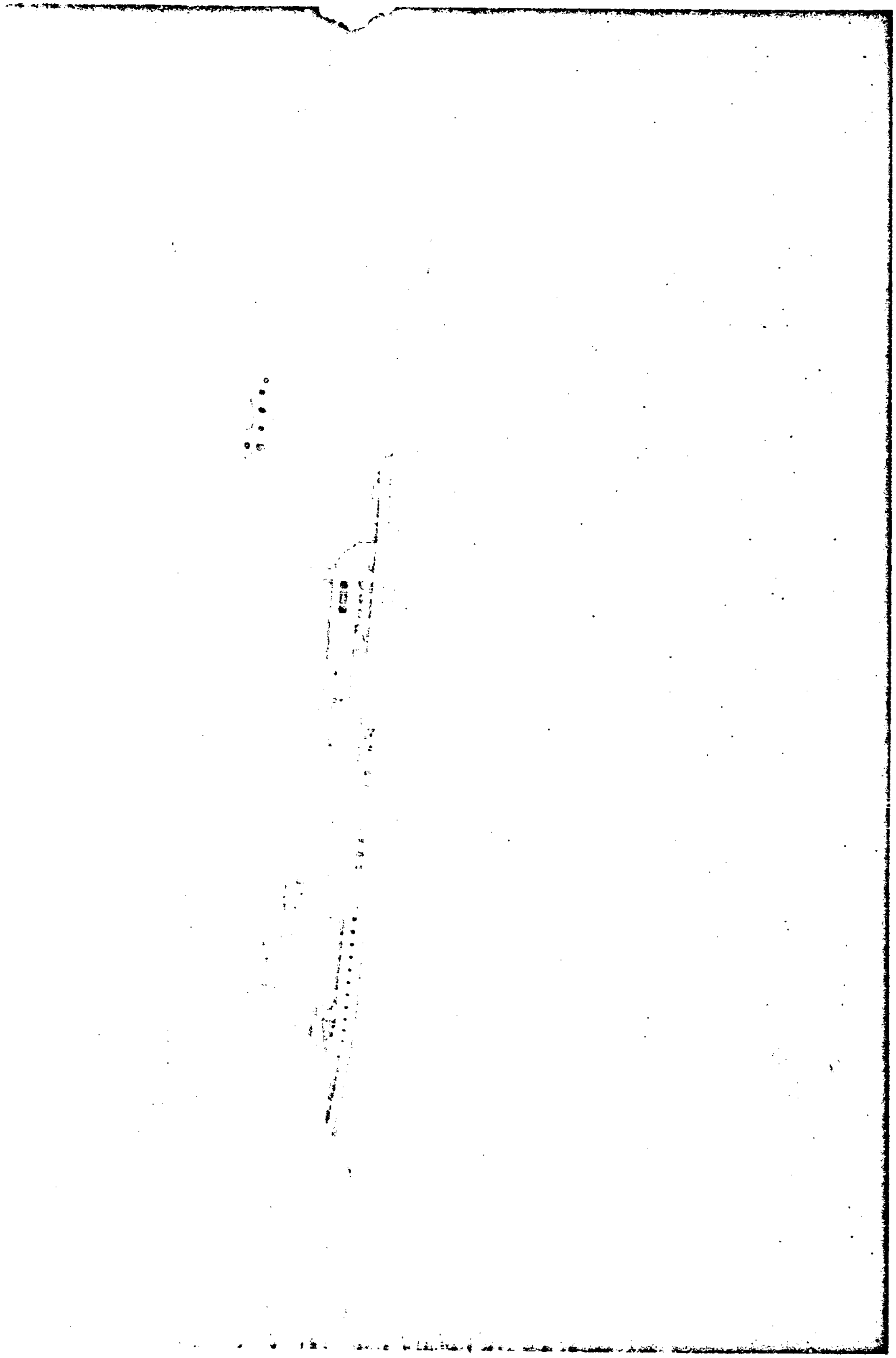

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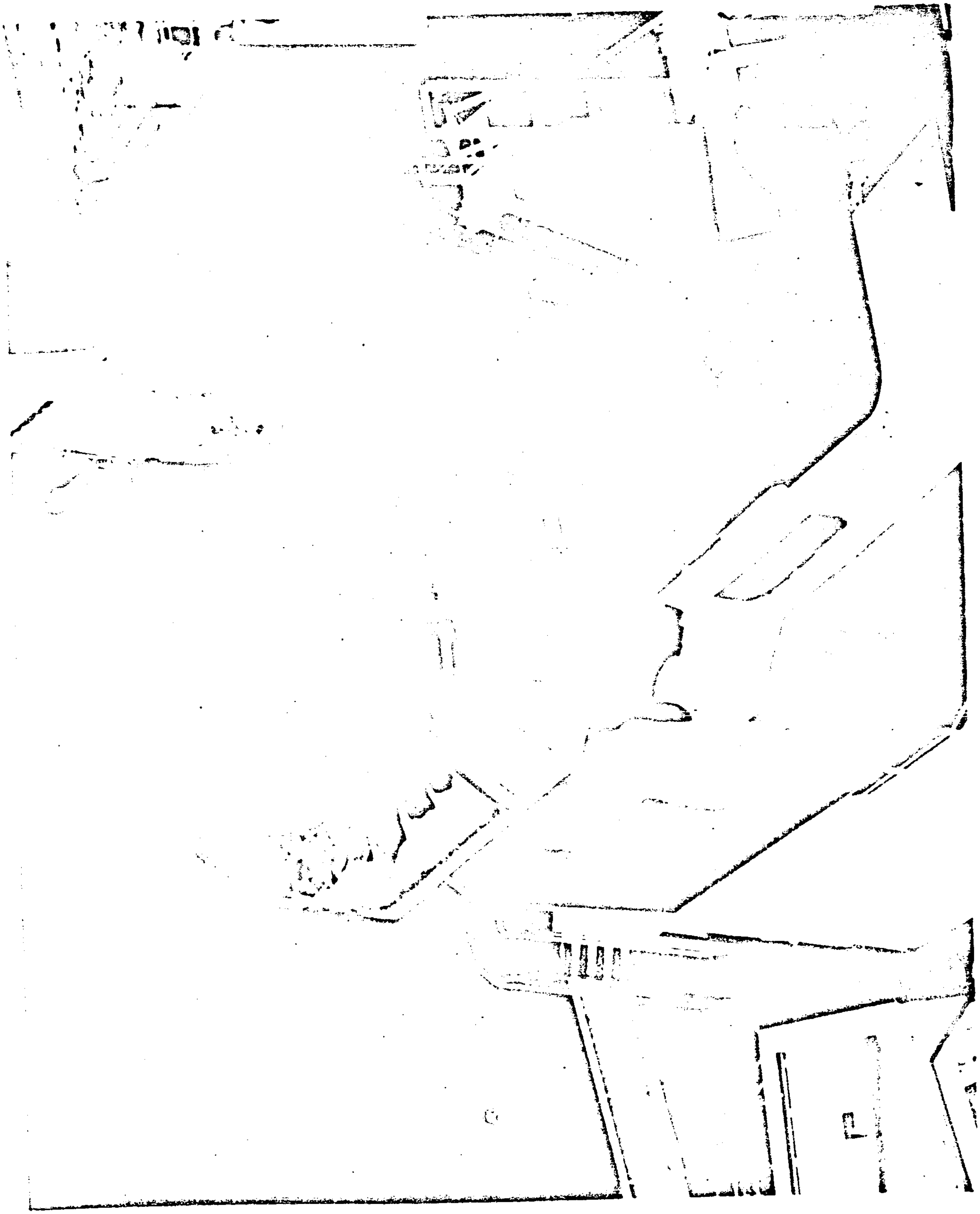

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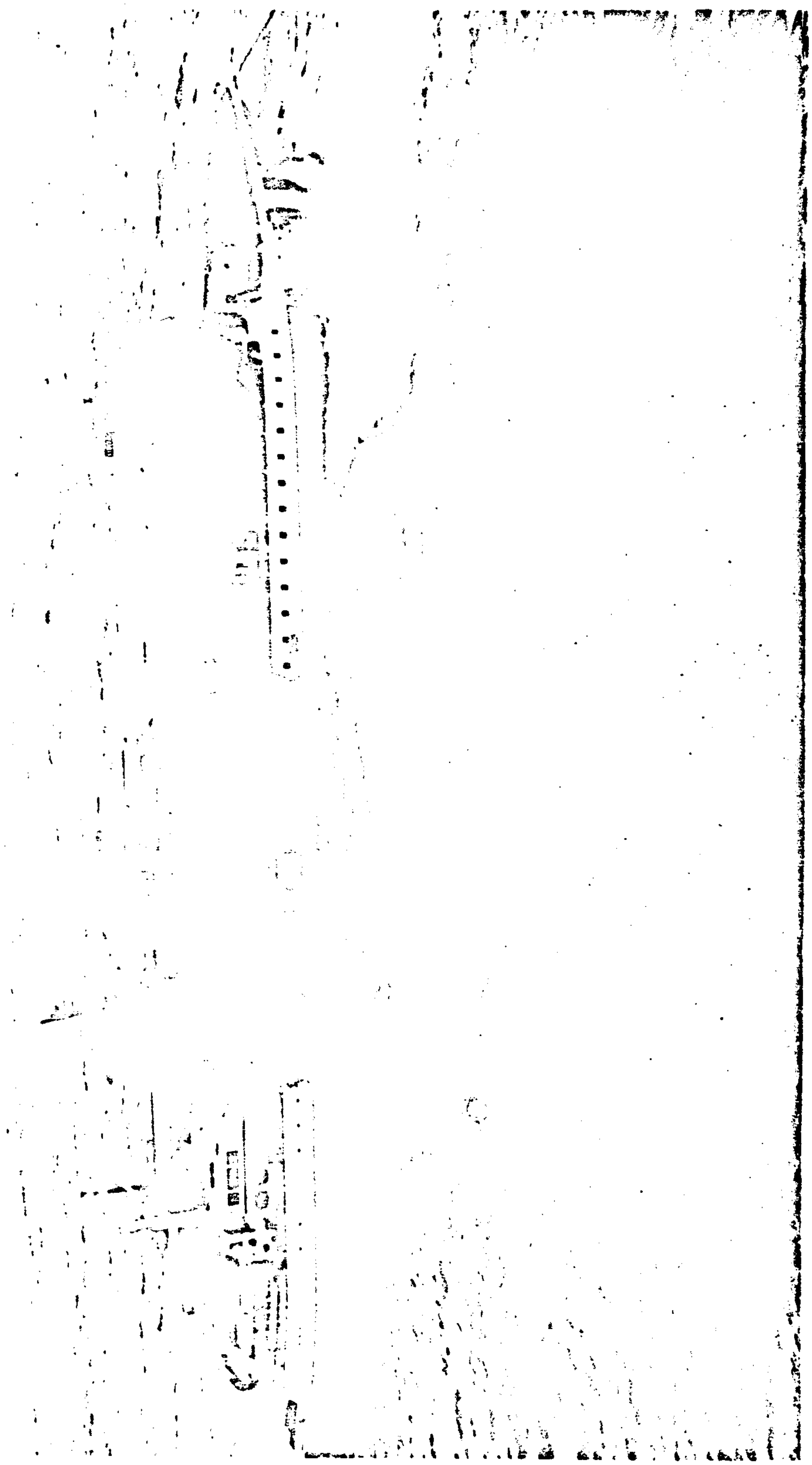

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Mr. James R. Nelson	FAA (ARD-301)
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Mr. David Ostrowski	FAA
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TILT ROTOR - Cont.

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Mr. R. Allen Price	Price Engr. Sales Inc.
Mr. J. P. Raney	NASA
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Dr. Leonard Roberts	NASA Ames Research Center
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Cmdr. Richard L. Schoel	U.S. Coast Guard
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Ms. Dora Strothers	Bell Helicopter Textron
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Mr. Robert L. Suggs	Petroleum Helicopters Inc
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Mr. Peter Talbot	NASA
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Mr. Gary Thompson	Verticare
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Mr. Curt Walker	U.S. Army
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Mr. William W. Walls	Boeing Vertol Co.
Mr. John F. Ward	NASA
Mr. Charles E. Webb	U.S. Navy
Mr. Gilbert J. Weden	U.S. Army Propulsion Lab.
Mr. Wilbur F. Wells	FAA
Mr. Ronald K. Wernicke	Bell Helicopter Textron
Mr. Thomas C. West	FAA
Mr. Keith Whittingslow	MBB Helicopter Corp.
Mr. Dale E. Williams	Goodyear
Mr. David E. Wright	Hughes Helicopters
Col. John F. Zugschwert	Department of the Army
Dr. John Zuk	NASA Ames Research Center

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Mr. Darral J. Freund	Vitro Laboratories

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Mr. Glen A. Gilbert	Glen A Gilbert & Associates
Mr. Ted Gittinger	Hughes Helicopters
Mr. Donald P. Gleiter	Naval Air Development Center
Mr. Joe E. Gray	Bell Helicopter Textron
Mr. Robert B. Greeno	High Country Helicopters
Mr. Milton Gregory	Computer Avionics Corp.
Mr. K. I. Grina	Boeing-Vertol Company
Mr. Mike Groen	NASA
Mr. Fred Groh	Pratt & Whitney Aircraft
Mr. Joseph C. Gross	Mobil Oil Corp.
Mr. E. E. (Tug) Gustafson	Tug Gustafson Associates
Mr. Bill Hacklen	The Rotor Works
Mr. Jake Hart	Aerospatiale Helicopter Corp.
Mr. Robert E. Head	Hughes Helicopters
Mr. Allen Henderson	RCA Avionics
Mr. Robert W. Hicks	Detroit Diesel Allison
Mr. S. M. Hudson	Detroit Diesel Allison, Div. of GMC
Mr. Ed Huff	NASA
Mr. Nick M. Hughes	Air Research Manufacturing
Mr. Russell Hull	Systems Control, Inc.
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Mr. Rod Iverson	Sperry Flight Systems
Mr. David S. Jenny	Sikorsky Aircraft Division
Mr. David Jensen	Rotor & Wing International
Mr. W. Johnson	NASA
Mr. David G. Jones Jr.	
Mr. Kenneth Jones	Offshore Logistics, Inc.
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Mr. Bob King	Hughes Helicopters
Mr. Kenny King	
Mr. Leo Kingston	Sikorsky Aircraft
Mr. Lewis Knapp	Sikorsky Aircraft
Mr. Charles Kuintzle	Avco Lycoming
Capt. Michael Kurth	
Mr. Anton J. Landgrebe	United Technologies Research Center
Mr. John A. Lasch III	U.S. ARMY
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Mr. Richard B. Lewis II	USAAVRADCOM
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Mr. Raymond E. Malatino	FAA
Mr. Roger K. Mark	Hughes Helicopters
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Mr. Joseph Mashman	Bell Helicopter Textron
Mr. Tom Mason	Aerospatiale Helicopters Corp.
Mr. Carl Matthys	Bell Helicopter Textron
Mr. Ken McElreath	Rockwell-Collins
Mr. Kenneth McFadden	Evergreen Helicopters Inc.
Mr. Frank McGuire	Helicopter News
Mr. Frank McHugh	Boeing Vertol Company
Mr. R. A. Megan	Pratt & Whitney of Canada

Mr. George Meyer	NASA
Mr. Donn E. Molyneux	Rayehem Corp.
Mr. Donald S. Monson	Detroit Diesel Allison
Mr. Duane Moore	Illinois Dept. of Transportation
Mr. Andrew Morse	US Army
Mr. Lonnie R. Nail	Tenneco Oil Exp. & Production
Mr. James R. Nelson	FAA (ARD-301)
Mr. Richard O'Lone	Aviation Week
Mr. David Ostrowski	FAA
Ms. Jo Ann Painter	A.V. Aviation, Inc., Heptr Sales
Mr. Weneth D. Painter	NASA-DFRC
Mr. T. H. Parker	Hughes Helicopters
Mr. Benton L. Parris	NASA
Mr. Peter H. Parsinen	Bell Helicopter Textron
Mr. James L. Parsons	RCA
Mr. Edward Pease	Avco Lycoming Div.
Mr. W. Peck	Boeing Vertol Co.
Mr. Jon Pellow	Heli-Flite Canada
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Mr. Greg Plechus	Aerospatiale Helicopter Corp.
Mr. David Poferl	NASA - Lewis Research Center
Mr. Samuel L. Porter	Naval Air Test Center
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Mr. J. P. Rancy	NASA
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Mr. Ron R. Reber	Bell Helicopter Textron
Mr. Robert A. Richardson	Helicopter Association of America
Dr. Leonard Roberts	NASA Ames Research Center
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Mrs. Wanda Rogers	Rogers Helicopters Inc.
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Dr. Kenneth M. Rosen	Sikorsky Aircraft
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Mr. Laurel G. Schroers	
Mr. Stephen A. Schuldenfrei	Helicopter Association of America
Mr. Rudy Schwarz	Rolls-Royce
Mr. Michael Scully	US ARMY
Mr. Archie T. Sherbert	Boeing Vertol Co.
Mr. John Shipley	Structures Lab, USARTL (AVRADCOM)
Mr. Robert Silver	Silver Instruments
Mr. Delford Smith	Evergreen Helicopters, Inc.
Mr. Henry G. Smith	
Ms. Kim Smith	Helicopter News
Mr. C. Thomas Snyder	NASA Ames Research Center
Col. Harold B. Snyder, Jr.	HQ TRADOC Ft Monroe, VA,
Mr. William J. Snyder	NASA Ames Research Center
Mr. S.L. Spear	Pratt & Whitney Aircraft Group GPD
Mr. Richard Spivey	Bell Helicopter Textron

Mr. M.D. Sroten	Pratt & Whitney Aircraft of Canada
Mr. Irwin Stambler	Aviation Convention News
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Mr. Warner L. Stewart	NASA Lewis Research Ctr.
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Ms. Diana M. Stuart	
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Mr. Robert L. Suggs	Petroleum Helicopters Inc
Mr. Stephen R. Sullivan	Aris Helicopters Ltd.
Mr. Geoff Sutton	Helicopter World
Mr. Hal Symes	Evergreen Helicopters
Mr. C.A. Syvertson	NASA Ames Research Center
Mr. Peter Talbot	NASA
Mr. P. Tanimoto	FAA
Mr. Rodney Taylor	Hughes Helicopters
Mr. Joel Terry	U.S. Army
Mr. Tommy H. Thomason	Bell Helicopter Textron
Mr. Bill Thompson	Air Logistics
Mr. Don Tooker	Piasocki Aircraft Corp.
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Mr. William W. Walls	Boeing Vertol Co.
Mr. John F. Ward	NASA
Mr. Gilbert J. Weden	U.S. Army Propulsion Lab.
Mr. Wilbur F. Wells	FAA
Mr. Ronald K. Wernicke	Bell Helicopter Textron
Mr. Thomas C. West	FAA
Mr. W. White	U.S. Army
Mr. John S. White	
Mr. Keith Whittingslow	MBB Helicopter Corp.
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Mr. David R. Woodley	Boeing Vertol Co.
Mr. David E. Wright	Hughes Helicopters
Comdr. R.W. Zins	U. S. Coast Guard
Col. John F. Zugschwert	Department of the Army
Dr. John Zuk	NASA Ames Research Center

HAA/NASA ADVANCED TECHNOLOGY WORKSHOP
EXECUTIVE SUMMARY
AERODYNAMICS AND STRUCTURES SESSION

CHAIRMAN	David S. Jenney	Sikorsky Aircraft
TECHNICAL SECRETARY	Robert J. Huston	NASA - Langley Research Center

Volume III of the Final Report presents the Aerodynamics and Structures segment of the workshop. This volume includes the identification of user needs in the areas of concern to this session as pointed out by the users on the first day of the workshop (see Volume II), combined with a summarization of the proceedings of the session. The session format consisted of opening remarks by the session chairman and the technical secretary. Then an overview of the related NASA technical programs was followed by presentations in four subsessions organized as follows:

Panel	Chairman	NASA Presentor
Performance	W. Walls	Wayne Johnson
Acoustics	R. King	J.P. Raney
Vibration	T. Gaffey	Robert J. Huston
Composites	J. Shipley	H. Benson Dexter

Other presentors included:

Jack Landgrebe
United Technologies Research Center

William Walls
Boeing Vertol

Charles Cox
Bell Helicopter Textron

William F. White, Jr.
U.S. Army (AVRADCOM)

E. Robert Wood
Hughes Helicopters

John L. Shipley
U.S. Army (AVRADCOM)

SUMMARY OF SESSION

The following Workshop Summary Forms outline user needs, technology requirements and status, and proposed R&D action as developed by this workshop session. These summaries deal with four sub-areas: Acoustics, Performance, Vibration, and Composites. The chairman's report of this session together with relevant presentations are contained in Volume III.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA AERO/STRUCT. SUB-AREA PERFORMANCE

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
ENGINE-OUT PERFORMANCE	VALIDATED LOW SPEED STEADY AND TRANSIENT PERFORMANCE ANALYSIS	EMPIRICAL METHODS USED. NO NASA ACTIVITY	. DEVELOP SUITABLE MATH MODEL AND SIMULATION . ACQUIRE LOW SPEED STEADY AND TRANSIENT WIND TUNNEL DATA. . ACQUIRE RSRA TEST DATA. . VALIDATE SIMULATION
FUEL EFFICIENCY - LOW FUEL CONSUMPTION - LONG RANGE - REDUCED DIRECT OPERATING COST	IMPROVE AIRCRAFT LIFT/DRAG RATIO (L/D)	. ADVANCED ROTOR PROGRAM; . STUDY OF FLOW FIELDS IN HIGH SPEED FLIGHT. . COMPOSITES PROGRAM TO REDUCE WEIGHT	ENDORSED PROGRAM
SPEED	INTEGRATED APPROACH TO POWER, NOISE, VIBRATION, LOADS, CONTROL	ADV. ROTOR AND SUPPORTING TECHNOLOGY	ALSO - DEVELOP WIND TUNNEL CAPABILITY TO MEASURE VIBRATION AND NOISE

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA AERO/STRUCT.   SUB-AREA ACOUSTICS

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
LOW EXTERNAL NOISE	. MEET NOISE RULES	LITTLE ACTIVITY	CONTINUE TIP IMPROVEMENT; MINIMIZE PENALTY OF LOW TIP SPEEDS.
	. DEFINE NOISE SOURCES	ANALYSIS IN WORK	UPGRADE WIND TUNNEL AND FLIGHT EVALUATION TECHNIQUES INCLUDING 40 x 80' TUNNEL.
	. PROVIDE A DESIGN-FOR-NOISE CAPABILITY	IN WORK. VERY LONG TERM.	CONSIDER SEMI-EMPIRICAL INTERIM METHODOLOGY.
	. QUANTIFY NOISE ANNOYANCE	IN WORK.	ENDORSE NEED FOR PROPER DESCRIPTOR.
LOW INTERNAL NOISE	. CRITERIA	IN WORK	CONTINUE PSYCHO-ACOUSTIC EFFORT.
	. NOISE REDUCTION MEANS	LITTLE NASA EFFORT	STUDY MEANS TO INTERRUPT STRUCTURAL PATH.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA AERO/STRUCT. SUB-AREA VIBRATION

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
INCREASE - SPEED, PAYLOAD, R/M WITH LOW VIBRATION OF LATEST MODERN HELICOPTERS	. REDUCE WEIGHT OF VIBRATION CONTROL	ADV. ROTOR PROGRAM	ENDORSED - STRESS VERSATILITY TO HANDLE PASSIVE AND ACTIVE APPROACHES.
	. IMPROVE PREDICTION CAPABILITY	IN WORK	PURSUE AIRFRAME RESPONSE ANALYSIS TO SUCCESSFUL CORRELATION. VALIDATE METHODS TO PREDICT ROTOR AND TAIL LOADS.
	. NEW CONCEPTS	IN WORK	SUPPORT HHC UNTIL FEASIBILITY IS CLEAR.
INCREASED SPEED, R/M WITH LOW VIBRATION	. EQUIPMENT FOR HELO ENVIRONMENT	NO NASA PROGRAM	AUGMENT TO STUDY TOLERANT POWERPLANTS, SUITABLE EQUIPMENT SPECS.
	. COMFORT CRITERIA	SOME ACTIVITY UNDER ACOUSTICS PROGRAM	DEVELOP CRITERIA INCLUDING MULTIPLE HARMONICS AND NOISE.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA AERO/STRUCT. SUB-AREA COMPOSITES

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
REDUCED WEIGHT LOWER COST RELIABILITY FUEL ECONOMY NO CORROSION CRASHWORTHINESS	ADVANCED COMPOSITES	FIRST GENERATION IN EVALUATION	ENDORSE FY '83 NEW INITIATIVES - . PRIMARY STRUCTURE . ENERGY ABSORPTION . LOWER COST . GREATER WEIGHT SAVING ALSO: IMPROVE STATIC AND FATIGUE ANALYSIS AND UNDERSTANDING OF FAILURE MODES TO MAXIMIZE POTENTIAL OF COMPOSITES.
LOW INTERNAL NOISE	ASSESSMENT OF BONDED STRUCTURE	EFFECTS ALMOST UNKNOWN	EVALUATE EFFECT OF BONDED STRUCTURE AND OF COMPOSITE PROPERTIES ON NOISE.

HAA/NASA ADVANCED TECHNOLOGY WORKSHOP
EXECUTIVE SUMMARY
FLIGHT CONTROL, AVIONICS AND HUMAN FACTORS SESSION

CHAIRMAN	Kenneth Jones	Offshore Logistics, Inc.
TECHNICAL SECRETARY	C. Thomas Snyder	NASA-Ames Research Center
RECORDING SECRETARY	Richard Kurkowski	NASA-Ames Research Center

Volume IV of the Final Report presents the Flight Control, Avionics, and Human Factors segment of the workshop. This volume includes the identification of user needs in the areas of concern to this session as pointed out by the user presentations on the first day (see Volume II), combined with a summarization of the proceedings of the session. The session format consisted of opening remarks by the session chairman and the technical secretary. Then an overview of the related NASA technical programs was followed by presentations in a Flight Control Technology Subsession and an All-Weather Operations Subsession.

The description of the NASA technical programs was performed by the following:

NASA Helicopter Flight Dynamics & Control Research
Robert Chen

NASA All-Weather Rotorcraft Program
John Bull

NASA Helicopter Man-System Integration Program
Ed Huff

The Flight Control Technology Subsession was comprised of the following:

Bruce Blake
Boeing Vertol

Rod Iverson
Sperry Flight Systems

Dora Strother
Bell Helicopter Textron

David Key
U.S. Army Aeromechanics Laboratory

Ted Carter
Sikorsky Aircraft

The All-Weather Operations Subsession was comprised of the following:

Ken McElreath
Collins Radio

Paul Pencikowski
Hughes Helicopters

Richard Cnossen
Magnavox

Larry Clark
Heliflight Systems

Both Subsessions were under the Chairmanship of Kenneth Jones.

SUMMARY OF SESSION

The following Workshop Summary Forms outline user needs, technology requirements and status, and proposed R&D action as developed by this workshop session. These summaries deal with three sub-areas: Flight Dynamics and Controls, All-Weather Operations, and Human Factors. The chairman's report of this session together with relevant presentations are contained in Volume IV.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA FLIGHT CONTROLS AND AVIONICS SUB-AREA FLIGHT DYNAMICS & CONTROLS

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
* Certification Criteria	* Stability Requirements	In progress	* Develop Data Base
	* Dual/Single Pilot IFR	In Progress	* Simulation and Flight Investigations with FAA
	* Simulator Requirements	In Progress	* Develop Reference Material - Math Modeling - Validation Procedures - Fidelity Requirements Cookbook
	* Software Verification & Validation for Digital Systems	In Progress	* Perform Analysis and Laboratory Investigations
			* Develop Tools & Techniques
			* Coordinate with FAA
* Optimum Take-Off Techniques	* Accurate Vehicle Performance Information	In Progress	* Develop Control/Display Systems Which Allow Full Use of Available Performance
		In Progress	* Develop Flight Test Techniques for Determination of Performance - F(β G.E., Control & Engine Response)
* Heavy Lift/Multi-Lift	* Advanced Control Systems	Planned	* Develop New Concepts for Ferrying and Load Placement
		Initiated	* Develop Multi-Aircraft Control Techniques- (e.g. Master/Slave)
* Flying/Ride Qualities	* Advanced Control Systems	Planned	* Develop Active Control Concepts - 1) For Emergency Situations - Engine Failure Transients - Automatic [illegible] ght Ditching - Tail Rotor Malfunctions

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA FLIGHT CONTROLS AND AVIONICS SUB-AREA FLIGHT DYNAMICS & CONTROLS

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
		Planned (Some in Progress)	2) For Improved Handling - Relaxed Static Stability - Gust Alleviation - Remove Cross Coupling-Including Propulsion/Flight Control - Vibration Suppression
		In Progress	* Investigate with Army multi-axis Force Gradient Controller
* Operational Reliability	* Improved Avionic Systems	In Progress	* Perform Analysis & Laboratory Investigations - Advanced Architecture - Software V&V - Hardened System Design - Lightning/EMI Tolerance
* Low Altitude Turbulence Velocity Profiles	* Existing	Some Past Work (None for Oil Rigs)	* Measure Turbulence & Velocity Profiles - Offshore Oil Rigs - Rooftops - Large Buildings
		In Progress	* Perform Small Scale Wind Tunnel Tests of Model Structures

COMMENT: NASA should acquire a modern twin engine helicopter for research in which control power and rotor dynamics play a part. Modern rotor systems are required for work in the frequency domain in which automatic control systems operate, and twin engine h/v limitations should be factored into terminal guidance solutions.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA FLIGHT CONTROLS AND AVIONICS SUB-AREA All Weather

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
* Remote Area Operation	* Accurate Low Altitude Navigation	Initiated	* Develop GPS for Rotorcraft Needs - Set Architecture & Interfaces - Differential GPS
	* Reliable Communications	None	* Work with FAA to Develop Satellite Voice Links
	* Obstacle Avoidance	In Progress	* Develop Multi-Spectral Imaging Techniques - IR, Radar, Pictorial Displays, Image Enhancement
	* Unimproved Landing Site Operations	In Progress	* Develop Approach Capability Using Airborne Radar, GPS, Loran, Low Cost Portable MLS
* Terminal Area Operations	* Integration with ATC	In Progress	* Simulation and Flight Evaluations - 3D/4D RNAV - Non-Interference with Conventional Traffic
		In Progress	* Develop- with FAA Data Links as Alternative to Voice Communication
	* Noise Reduction	In Progress	* Develop Operational Flight Profiles to Confine Noise Footprint.
	* Low-Cost Integrated Avionics	In Progress	* Develop and Demonstrate an Advanced Low Cost, Integrated Category III Avionics System for Civil Helicopters

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA FLIGHT CONTROLS AND AVIONICS SUB-AREA All Weather

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
* Certification Criteria	* Operational Criteria	In Progress	* Assist FAA in Defining IFR Criteria-TERPS, etc.
* IFR Low Speed and Hover	* Accurate Vehicle Position & Velocity Information	In Progress	* Develop Accurate Low Airspeed Sensor
		In Progress	* Display Development
		In Progress	* Low Cost Attitude & Heading Reference System

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA FLIGHT CONTROLS AND AVIONICS SUB-AREA HUMAN FACTORS

USER NEED	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
* Reduced Pilot Workload	* Advanced Cockpit Design	In Progress	* Develop System Functions to Allow Pilot to Act as Manager.
		In Progress	* Develop Integrated Controller
		None	* Coordinate with Government, Civil, Foreign Agencies in Development of Standardized Displays and Controls
		In Progress	* Develop Cockpit Configurations with Maximum Field of View - (Sidearm Controllers, Audio/Visual/Tactile Pilot Information Options).

HAA/NASA ADVANCED TECHNOLOGY WORKSHOP
EXECUTIVE SUMMARY
PROPULSION SESSION

CHAIRMAN	Charles Kuintzle	Avco Lycoming
TECHNICAL SECRETARY	Warner Stewart	NASA-Lewis Research Center

Volume V of the Final Report presents the Propulsion segment of the workshop. This volume includes the identification of user needs in the areas of concern to this session as pointed out by the user presentation on the first day (see Volume II), combined with a summarization of the proceedings of the session. The session format consisted of opening remarks by the session chairman and the technical secretary. Then an overview of the related NASA technical programs was followed by presentations in an Airframer Subsession and a Propulsion Subsession.

The description of the NASA technical programs was performed by D. Poferl of NASA-Lewis Research Center.

The Airframer Subsession was conducted by the following:

Dr. Kenneth Rosen
Sikorsky Aircraft

Carl Matthys
Bell Helicopter Textron

Rodney Taylor
Hughes Helicopters

Gilbert Beziak
Aerospatiale Helicopter

David Woodley
Boeing Vertol

The Propulsion Subsession was conducted by the following:

S M. Hudson
Detroit Diesel Allison

Arnold Brooks
General Electric Co.

Nick Hughes
AiResearch Manufacturing

Richard McLachlan
Pratt & Whitney Aircraft of Canada

Dennis Lewis
Rolls Royce, Ltd.

Edward Peace
Avco Lycoming

Both Subsessions were under the Chairmanship of Charles Kuintzle.

SUMMARY OF SESSION

The following Workshop Summary Forms outline user needs, technology requirements and status, and proposed R&D action as developed by this workshop session. These summaries deal with two sub-areas: Airframe Manufacturers' Technology Needs, and Engine Manufacturers' Technology Needs. The chairman's report of this session together with relevant presentations are contained in Volume V.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION SUB-AREA ENGINE TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Real OEI Contingency Power	Contingency Power Program in early planning phases to explore economic penalties and feasibility of emergency power. Will investigate "burnout power" requirements and certification methods.	Major emphasis should be directed to this program. Should be reassessed in view of priority placed upon this area by users and manufacturers. A joint user, industry, NASA, and FAA Workshop on OEI Contingency Power Ratings should be the vehicle to formulate the general regulatory and technological approaches to meet this requirement.
Improved Reliability (Reduced Noise)	o Transmission (conventional) o Transmissions (unconventional) o Very Large Transmissions o Diagnostics All of these programs involve technology development targeted toward improved powerplant reliability. The transmission program combine the strengthening of design approaches as well as increased life, reduced weight, and reduced noise. Diagnostics program is study activity to identify diagnostic and monitoring systems to improve system safety and reliability.	Programs are all well structured and, if successful should yield technology developments that will improve reliability of future powerplants. Some of the objectives are somewhat incompatible, i. e. improved reliability, reduced noise vs reduced weight, reduced cost. Currently, users would accept improved reliability and reduced noise at equal (and probably higher) weight and cost.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION SUB-AREA ENGINE TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Advanced Powerplant Concepts	o Advanced Propulsion Systems o Convertible Engine System Technology The Advanced Propulsion System Program supports studies targeted at advanced conceptual designs. The Convertible Engine Program is an evaluation activity to demonstrate transfer of fan thrust to shaft power using variable exit guide vanes.	Both of the current programs are endorsed. The propulsion studies should be extended to include the reevaluation of tip propulsion with latest technology developments.

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA PROPULSION

SUB-AREA AIRFRAME TECHNOLOGY

User Requirement	Current Related NASA Program	Recommendations for Future
Improved Range	o Compressors o Combustors o Turbines These programs are all directed at extending the basic technology areas related to the design and development of advanced components for high pressure ratio, high temperature, high performance turbine engines.	These programs are strongly endorsed. They provide the nucleus of basic research and development in the aerothermodynamics of turbine engines. Objectives cover a very wide scope considering the funding levels available. Regenerators for aviation gas turbines should be addressed. This currently untapped potential could yield larger improvements in aircraft range in a shorter time frame than the evolution of other component technology.
Improved All-Weather Capability	Icing Program is directed at several areas including:- o Analytical activities directed at droplet trajectories and inter-actions with engine inlets along with experimental verification thereof. o Development of research models and ice protection concepts. o Update icing facilities.	This program is well structured and is endorsed, however, large scope of program objectives relative to limited level of funding.

HAA/NASA ADVANCED TECHNOLOGY WORKSHOP
EXECUTIVE SUMMARY
VEHICLE CONFIGURATION SESSION

CHAIRMAN	Stanley Martin, Jr.	Bell Helicopter Textron
TECHNICAL SECRETARY	Wally Deckert	NASA-Ames Research Center

Volume VI of the Final Report presents the Vehicle Configuration segment of the workshop. This volume includes the identification of user needs in the areas of concern to this session as pointed out by the user presentations on the first day (see Volume II), combined with a summarization of the proceedings of the session. The session format consisted of opening remarks by the session chairman and the technical secretary. Then an overview of the related NASA technical programs was followed by presentations in a High Speed Vehicle Configurations Subsession and a Large Rotorcraft Configuration Subsession.

The description of the NASA technical programs was performed by William Snyder of NASA-Ames Research Center.

The High Speed Vehicle Configurations Subsession was organized as follows:

Subsession Chairman

Lewis Knapp
Sikorsky Aircraft

Members

Rodney K. Wernicke
Bell Helicopter Textron
(Tilt Rotor)

Leo Kingston
Sikorsky Aircraft
(X-wing)

Andrew Logan
Hughes Helicopters
(Compound concepts)

Ted Carter
Sikorsky Aircraft
(Advancing blade)

Frank McHugh
Boeing Vertol
(High speed)

William Thompson
Air Logistics, Inc.

Capt. M.J. Evans
British Airways Helicopters

John Magee
Ames Research Center

Dr. Michael Scully
U.S. Army Research

Elmer (Tug) Gustafson
Tug Gustafson Associates

Thomas C. West
FAA

The Large Rotorcraft Vehicle Configurations Subsession was organized as follows:

Subsession Chairman

Gordon Fries
Boeing Vertol

Members

Ted Carter
Sikorsky Aircraft
(Multi-lift)

Robert E. Head
Hughes Helicopters
(Single rotor, tip drive)

John Schneider
Boeing Vertol
(Multirotor heavy lift)

Frank Piasecki
Piasecki Aircraft Corp.
(Hybrid airship)

Hal Symes
Evergreen Helicopters

James Lematta
Columbia Helicopters

Capt. M.J. Evans
British Airways Helicopters

Dr. Michael Scully
Army Research and Technology

Peter Talbot
Ames Research Center

Elmer (Tug) Gustafson
Tug Gustafson Associates

Thomas C. West
FAA

At this juncture in the Session, a special presentation on opportunities for military and civil-commercial rotorcraft cooperation was made by Colonel John Zugschwert of HQ, U.S. Department of the Army.

SUMMARY OF SESSION

The following Workshop Summary Forms outline user needs, technology requirements and status, and proposed R&D action as developed by this workshop session. These summaries deal with two sub-areas. High Speed Rotorcraft Concepts, and Large Rotorcraft Concepts. The chairman's report of this session together with relevant presentations are contained in Volume VI.

TABLE I

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
1. FIRST PRIORITY			
Safety	An overriding consideration		Perform design studies of proposed configurations to identify at an early point any unsafe characteristics.
Zero rejected Takeoff Distance, OEI	Effects of: - Power required in low speed flight - Rotor disposition for multi-rotor configurations		Conduct flight tests to determine takeoff performance of single-rotor, tandem-rotor, and side-by-side rotor aircraft. Correlate with analysis.
Reliability	Not a direct configuration research driver		None
Noise	Understanding of rotorcraft external noise sources, particularly as influenced by aerodynamic interference during takeoff and landing		Measure noise generated by current advanced rotorcraft Develop theory to predict noise
Speed	See separate listing, Table II		

TABLE 1 (Cont'd)

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations

SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
2. SECOND PRIORITY			
Range	A function of: - propulsive efficiency - weight of fuel carried - L/D - specific fuel consumption of engine(s)		Initiate research tasks directed at aerodynamic improvement of propulsive devices, reduction in weight empty to gross weight ratio and drag reduction For reduced engine sfc, see the Propulsion Session
Fuel efficiency	- increased nautical miles per pound of fuel consumed		See above
Protected/No tail rotor	Multi-rotor configurations, alternate antitorque systems for single-rotor helicopters		None
Mission flexibility	A fallout of other vehicle attributes		None
Ground disturbance	Understanding of disc loading, gross weight, rotor disposition effects		Literature survey Flight and tiedown tests with existing rotorcraft of differing configuration and gross weight
Large size	See separate listing, Table II		

TABLE I (Cont'd)

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
3. THIRD PRIORITY Crashworthiness Compact Agility Load handling	Not configuration research drivers		None

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TABLE II

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
Speed	Configurations considered:		
	High Speed Helicopter		
	Rotor operation at high inflow, advance ratio and Mach number		Define high speed helicopter
			Perform small-scale model tests
	High speed airfoils		Develop flightworthy full-scale rotor
	Drag reduction		Test in NASA 80 x 120 foot wind tunnel and in flight
	Compound		
	None required		None
	ABC		
	Flight envelope expansion		Complete XH-59A flight tests
	Integrated propulsion system with wide rpm range		Develop technology for an integrated engine and propulsor to operate efficiently over a wide rpm range
	Rotor hub drag reduction		Fly available rotor head fairing
	Reduced weight empty and improved rotor performance		Study rotor weight benefits from use of composite materials, performance benefits from optimized aerodynamics

TABLE II (Cont'd)

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
	Vibration alleviation		Investigate higher harmonic control for vibration alleviation in conjunction with FBW
	Effect of size		Determine effect of size on design for gross weights over 40,000 lb
	Tilt Rotor		
	Flight envelope expansion		Continue XV-15 flight tests
	Engines that operate efficiently over wide rpm range		Develop technology for engines to operate at high power, low sfc over wide rpm range
	Drag reduction		Investigate drag reduction, reduced empennage size, different empennage configurations
	Reduced weight empty		Study benefits of FBW and composite wing
	Improved rotor performance		Continue NASA Advanced Technology blade development
	Effect of size		Determine effect of size on design for gross weights over 40,000 lb
	X-wing		
	Fundamental technology		None - pending outcome of ongoing DARPA program

TABLE II (Cont'd)

WORKSHOP SUMMARY FORM

WORKSHOP TECHNOLOGY AREA Vehicle Configurations

SUB-AREA High Speed Concepts/ Large Rotorcraft Concepts

USER NEEDS	TECHNOLOGY REQUIREMENT	PRESENT STATUS	PROPOSED R&D ACTION (NASA/INDUSTRY)
Large Size	Configurations considered:		
	Tip driven, Single rotor		
	Not applicable pending results of reassessment		Reassess in view of today's technology
	Tandem rotor, Shaft driven		
	Transmission design		Bench test XCH-62 transmissions
	Large rotorcraft technology base		Evaluate completing XCH-62 for flight test
	Multi-Lift		
	Master-slave control laws		Develop control laws on NASA simulator
	Interconnect beam structural concepts		Consider flight demonstration
	Hybrid		
	Flight evaluation		Reassess following completion of current program

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HAA/NASA TILT ROTOR WORKSHOP
EXECUTIVE SUMMARY

CHAIRMAN	John Magee	NASA-Ames Research Center
TECHNICAL SECRETARIES	James Lane	NASA-Ames Research Center
	Demo Guilianetti	NASA-Ames Research Center

Volume VII of the Final Report presents the results of the Tilt Rotor Workshop. Following a demonstration flight of the XV-15 tilt rotor aircraft at Ames Research Center in the morning session of the workshop, a discussion of the technical characteristics of the aircraft was conducted by the chairman. These are detailed in Volume VII along with a summary of the discussions, including questions, answers and statements by participants.

TILT ROTOR EXPERIMENTS

An important element of the workshop was to consider views as to additional experiments with the XV-15 which it was felt NASA should perform in the future. These are set forth in the following summary.

TILT ROTOR EXPERIMENTS

(BASIC (UNMODIFIED) AIRCRAFT)

SUBJECT/TEST		SUBMITTED BY:
CRITERIA & ENGINEERING DEVELOPMENT DATA		
CERTIFICATION CRITERIA	o CONDUCT TESTS ASSOCIATED WITH FAA CERTIFICATION & ACCUMULATE VTOL/STOL PERFORMANCE & NOISE DATA	BOEING (GRINA)
	o INVESTIGATE TECHNIQUES FOR ABORTED TAKEOFFS & LANDINGS. DEFINE CRITERIA	BOEING (GRINA)
	o INVESTIGATE EMERGENCY CONDITIONS, INCLUDING CONVERSION AFTER POWER FAILURE AND AUTOROTATION	BOEING (GRINA)
	o DEMONSTRATE NORMAL ACCELERATION & MANEUVER CAPABILITY THROUGH TRANSITION	BOEING (GRINA)

ENGINE DESIGN DATA	o COLLECT ENGINE POWER TIME HISTORIES (TRANSIENTS, CYCLIC, STEADY) & ASSESS DAMAGE CONTENT OF MECHANICAL AND THERMAL LOW CYCLE FATIGUE MODES - SUGGESTED MISSIONS - OIL PLATFORM RESUPPLY, IFR CRUISE, GCA APPROACH, VERTICAL LANDING	DETROIT DIESEL ALLISON (W. L. MC INTIRE)
IFR	o PERFORM HOODED CONVERSIONS & RECONVERSIONS TO ASSESS WORKLOAD	BELL (ROD WERNICKE)
	o PERFORM HOODED INSTRUMENT APPROACHES & TOUCHDOWNS *	BELL (ROD WERNICKE)
NOISE	o NEAR AND FAR FIELD NOISE MEASUREMENTS TO DETERMINE POTENTIAL FOR COMMUNITY NOISE PROBLEMS	AMERICAN AIRLINES (RICHARD LINN)

STOL OPERATION	o DEMONSTRATE RAPID ACCELERATION & DECELERATION FOR MINIMUM RUNWAY LENGTH, EXAMINE V_{MIN} CONTROL	BELL (ROD WERNICKE)
NAVIGATION	o NAVIGATE ON DISCRETE NARROW WIDTH R_{NAV} ROUTES. QUALIFY FTE (FLIGHT TECHNICAL ERROR)	GLEN GILBERT (HAA)
NAV/TERMINAL AREA	o EVALUATE TRANSITION FROM VTOL (HELICOPTER) TO CTOL (AIRPLANE) & CTOL TO VTOL IN TERMINAL AREA ENVIRONMENTS UNDER ATC PROCEDURES. USE R_{NAV} SID'S & STAR'S	GLEN GILBERT (HAA)
	o EVALUATE TRANSITION FROM CTOL TO VTOL ON INSTRUMENT APPROACHES. PERFORM PRECISION & NONPRECISION APPROACHES *	GLEN GILBERT (HAA)

NAV/TERMINAL AREA (CONT.)	o PERFORM MISSED APPROACH INSTRUMENT PROCEDURES.* DETERMINE AIRSPACE REQUIREMENTS, BOTH AS VTOL AND IN TRANSITION VTOL TO CTOL	GLEN GILBERT (HAA)
	o EVALUATE TERPS CRITERIA IN RELATION TO VTOL & CTOL PERFORMANCE	GLEN GILBERT (HAA)
	o DETERMINE MINIMUM AIRSPACE REQUIRED FOR HOLDING AS A VTOL	GLEN GILBERT (HAA)
	o EVALUATE EFFECTS OF ATC SPEED CONTROL IN TERMS OF VEHICLE PERFORMANCE AND TIME RESPONSE REQUIREMENTS	GLEN GILBERT (HAA)
	o AUTOMATIC GUIDANCE SYSTEM (REQUIRES V/STOLAND INSTALLATION)	SPERRY (R.H. WAGNER)

CIVIL MARKET APPLICATIONS

OFFSHORE OIL PLATFORM	o DEMONSTRATE HANDLING QUALITIES IN OIL RIG & SHIP ENVIRONMENTS - E.G. INVESTIGATE CONTROL REQUIREMENTS & HQ WITH ROTOR PARTIALLY OVER EDGE OF PLATFORM OR DECK AND OPERATION IN TURBULENCE	BELL (R. WERNICKE) & BOEING (GRINA)
COMMUTER AIRLINE	o PERFORM ELEMENTS OF COMMUTER AIRLINE FLIGHT PROFILES (CLIMB, DEPARTURE, CRUISE, DESCENT, HOLDING, ETC). ASSESS PASSENGER, USER, & COMMUNITY ACCEPTANCE	BHT (R. WERNICKE) & BOEING (GRINA)
	o SIMULATE SCHEDULED OPERATION TO DEVELOP IN-SERVICE DATA ON PASSENGER HANDLING, NOISE, EFFECT ON WAKE ON LIGHT AIRCRAFT IN VICINITY, ETC.	BOEING (GRINA)

TECHNOLOGY	o CONTINUE THE EMPHASIS ON SOLVING THE STRUCTURAL DYNAMICS DIFFICULTIES, INCLUDING THOSE YET TO BE UNCOVERED DURING THE ENVELOPE EXPANSION TESTS. EVEN THOUGH SOME OF THESE SOLUTIONS MAY BE VEHICLE SPECIFIC, THEY ARE IMPORTANT FOR CORRELATION PURPOSES TO PROVE OUR ANALYTICAL METHODOLOGY.	BELL (S. MARTIN)
	o AS A CONTRIBUTION TO THE ABOVE, WE NEED TO INSTALL THE STIFFER CONVERSION SPINDLES AS SOON AS THE PROGRAM SCHEDULE WILL ALLOW.	BELL (S. MARTIN)
	o LATER IN THE PROGRAM SCHEDULE, WE SHOULD TRY A REDUCED TAIL SIZE, SINCE IT IS RELATIVELY EASY TO DO, WILL SAVE WEIGHT, AND SHOULD GREATLY REDUCE THE TAIL BUFFET THAT OCCURS DURING CONVERSION. EVENTUALLY, WE MIGHT TRY A SINGLE VERTICAL FIN TAIL CONFIGURATION AND PERHAPS A T-TAIL.	BELL (S. MARTIN)

TECHNOLOGY (CONT.)	o THE ADVANCED TECHNOLOGY BLADES NOW UNDER EVALUATION BY NASA OFFER SUBSTANTIAL IMPROVEMENTS IN STATIC THRUST, PROPULSIVE EFFICIENCY, AND DYNAMIC STABILITY. THIS PROGRAM SHOULD MOST CERTAINLY BE PURSUED AGGRESSIVELY, REGARDLESS OF WHO WINS THE COMPETITION.	BELL (S. MARTIN)
	o FLY-BY-WIRE OR LIGHT CONTROLS, PERHAPS TIED IN WITH THE V/STOL AND NASA PROGRAM, WOULD OFFER INTERESTING POSSIBILITIES TO NOT ONLY REDUCE THE WEIGHT EMPTY, BUT ENHANCE THE HANDLING QUALITIES AND ENABLE A NUMBER OF INTERESTING EXPERIMENTS IN ADAPTIVE CONTROLS TO BE PERFORMED.	BELL (S. MARTIN)